

**EVALUATION OF A PRACTICAL COMPONENT OF
THE BIOLOGY COURSE OF THE BASIC
UNIVERSITY SCIENCE COURSE EXPERIMENTAL
PROJECT AT UNIVERSIDADE EDUARDO
MONDLANE IN MAPUTO**

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COURSE EXPERIMENTAL PROJECT AT UNIVERSIDADE
EDUARDO MONDLANE IN MAPUTO**

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**A research report submitted to the Faculty of Science, University of the
Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the
degree of Master of Science.**

Johannesburg, December 1997.

DECLARATION

I declare that apart from the assistance acknowledged, this report is my own, unaided work. It is submitted in partial fulfilment of the requirements for the degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination in any other university.

Eugenia Flora Rosa Cossa

_____ day of December 1997

ABSTRACT

The purpose of this study was to determine whether the goals of the practical component of the cytology section of the biology course at Basic University Science Course Experimental Project (BUSCEP) at Universidade Eduardo Mondlane in Maputo were being achieved. Two kinds of instruments were used in this study. They were (i) a written practical test and (ii) an observation schedule (checklist I and II). A total of 41 first year biology students of the BUSCEP course were involved in the study. The written practical test determined whether the students had mastered the knowledge of the parts of the microscope and their functions and whether they had *understood* how to use the microscope. Checklist I tested whether the students had mastered the physical skills necessary to operate a light microscope correctly. Checklist II tested whether the students had mastered the skills needed to prepare a wet mount slide.

The results revealed that the goals of the practical component of the cytology section of the biology course at BUSCEP were not achieved. This was because most students have problems in understanding how to use the microscope as well as in mastering the logical sequence of the skills needed for effective use of the microscope. It is imperative that teachers find and use effective ways of assessing laboratory activities and skills during practicals, as this will contribute to the improvement of the BUSCEP biology course.

ACKNOWLEDGEMENTS

I would like to express my gratitude to a number of people without whose help this study would have been impossible.

- Deborah Osberg, my supervisor, Susan McCarthy and Dee Pinto, my co-supervisors, for their patience, valuable assistance, guidance and constructive criticism during the course of this study.
- The Botany Master room colleagues who gave me a lot of encouragement to carry out my study in the hardest moments.
- Bernard Grossjohann, for access to the first year biology students at BUSCEP as well as to all students who spared their time for this study.
- Peter Fridjhon, for his assistance with the statistical methods.

DEDICATION

Special dedication to my family, my husband Rogério Cossa and our children Suzana and Pitágoras, without whose sacrifice, patience and support completion of this study would have been impossible. I am also so grateful to my niece Gravelina who spent nights and days supporting my husband to take care after our children.

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CHAPTER 1

INTRODUCTION

1. BACKGROUND TO THE PROBLEM

The Basic University Science Course Experimental Project (BUSCEP) started as a project involving the Universidade Eduardo Mondlane (UEM) in Maputo and the Vrije Universiteit Amsterdam (VUA) in the Netherlands. The development of the project has been in three phases: The first phase from 1985 to 1989, involved first year students initially of the Faculty of Agronomy and later of Engineering, Biology and Physical Science. The second phase from 1990 to 1992 marked a period during which other faculties (Veterinary Science and Medicine) joined BUSCEP and the number of the students increased. During the third phase from 1992 to 1997, the Faculty of Science was established at UEM, and BUSCEP became the Basic Science Department within the Faculty of Science. Due the curriculum reforms in 1995, the Faculties of Veterinary Science and Medicine decided to withdraw from BUSCEP. BUSCEP is currently responsible for teaching the common semester courses of the Biology, Physics and Chemistry departments and Agronomy and Engineering Faculties. The subjects offered at BUSCEP are: Mathematics, Biology, Physics, Chemistry, Computer Awareness, English, Technical Drawing and Study Skills. For example, a biology student will take all subjects except Technical Drawing.

BUSCEP has three important goals: Firstly, it aims to train the Mozambican project staff for participation in mathematics and science education research. The policy of science education at UEM is to stimulate academic staff development and provide career opportunities. The policy aims to provide more solid insight in the learning problems of the first year students which will eventually lead to direct application of results to improve both the content of courses and teaching methodologies. Secondly, as students entering BUSCEP have different abilities and knowledge, BUSCEP aims to

bring everyone to roughly the same level in terms of content. The third and most important aim is to develop a range of practical skills among science students.

The role of practical work in science curricula worldwide is a major topic for discussion (Woolnough & Allsop, 1985). Most science teachers and lecturers consider laboratory sessions as a necessary and essential part of teaching in science (Gallagher, 1987). In addition, Bates (1978) and Hofstein & Lunetta (1982) argue that laboratory teaching is seen as a better method than other methods (viz. demonstrations and lectures) for teaching experimental skills and techniques. Tamir (1977) indicates that laboratory activities constitute a means of providing opportunities for observations to be made and for student experimentation. The uniqueness of the laboratory consists of providing students with opportunities to engage themselves in the process of investigation and inquiry. Piaget's work, according to Sanders (1988), suggests that laboratory experiences, as a component of the curriculum, should facilitate meaningful learning. According to Ausubel, learning will only be meaningful if a new idea or concept to be learned is consciously related by the learner to relevant concepts which the learner already knows (Sanders, 1988). Inquiry-based practical work can help the learner to make such links. If this linkage does not occur, then rote-learning or memorization is likely to result (Sanders, 1988). Dekker & Fraser (1989) state that the emphasis being placed on meaningful learning and the development of students' cognitive and motor skills, indicates that there is no substitute for practical work. The same authors claim that the theoretical and practical components of teaching biology cannot be separated.

However, in spite of claims about the effect of practical work on improving learning, several authors claim that practical work does not always appear to promote meaningful learning (Head, 1982; Novak, 1984; West & Pines, 1985; Driver & Bell, 1986). According to Fuller & Heyneman (1989), a science laboratory does not always stimulate student achievement and the high status given to laboratory activities is not justified. Clearly the way in which practical work is done can have a great influence on

its success.

One area of practical work which is fundamental to the study of biology is the use of the microscope, one of the basic tools of the biologist. It is important for students to have the knowledge and skills to carry out simple studies using the microscope as an investigative tool. It takes time and effort on the part of the educator and learner to successfully develop the range of skills required for the effective use of the microscope. According to Barker (1981), while students are often able to write down the steps involved in the use of the microscope, many are unable to implement them physically. So it is important to assess the laboratory activities and skills in order to determine whether the students have in fact mastered these skills.

There is a growing concern about the assessment of laboratory activities in general. Research indicates there is little doubt that teachers' assessment procedures for biology influence the way the students apply their knowledge during practical work (Bates, 1978; Hofstein & Lunetta, 1982; Johnstone & Wham, 1982; Tobin & Gallagher, 1987; Fuller & Heyneman, 1989; Wilson & Stensvold, 1991). Quisenberry (1982) states that if laboratory activities are considered as being essential, then they should be assessed. Systems for evaluating student activities in the laboratory can be classified into four broad categories: written reports, paper-and-pencil tests, laboratory practical examinations and observational assessment.

Two of the most common assessment methods traditionally used in our biology course at BUSCEP are the written laboratory report and paper-and-pencil tests. Eglen & Kempa (1974) and Doran & Dietrich (1980) report that these assessment methods do not provide direct information about students' skills in manipulating equipment, observing, organizing and performing an investigation efficiently. Sole dependence on laboratory reports in evaluating laboratory activities can lead students to copy from one another or to invent data (Eglen & Kempa, 1974; Doran & Dietrich, 1980). Some science teachers give students practical examinations to assess the acquisition of

manipulative skills, observational abilities and more complex problem-solving and process skills (Eglen & Kempa, 1974; Doran & Dietrich, 1980). Tamir (1974) outlined an inquiry-oriented laboratory examination and marking scheme which was designed to measure students' ability to solve novel problems in the laboratory.

The three systems of evaluation discussed above have some limitations regarding the breadth of skills that can be measured. Therefore more continuous systems of observational assessment have been developed, especially in the United Kingdom (Bryce, McCall, MacGregor, Robertson & Weston, 1983) and Israel (Cohen, Ben Zvi, Hofstein & Samuels, 1978). In observational assessment, the teacher unobtrusively observes and rates each student during a normal laboratory activity. Observation can be recorded over an extended period of time or during a single laboratory activity. Teachers can also distribute checklists of skills to their students and ask them to rate themselves after each laboratory session or at completion of a unit. However, Bryce & Robertson (1985) caution that in many areas of practical science assessment, detailed checklists can be unsuitable instruments for the assessment of some aspects of laboratory activities. They suggest that the use of checklists by a teacher during an informal, on-going experimental session must take into account not only the difficulties incurred in operating several checklists at one time but also the common practice in schools of pupils working in pairs or small groups. Any procedure adopted must offer the possibility of an objective and valid assessment of each individual pupil within the class (Bryce & Robertson, 1985).

2. STATEMENT OF THE PROBLEM

The aims of the biology course at BUSCEP are to develop a range of practical skills and to bring all students to the same level of abilities and knowledge. However, as a biology teacher at BUSCEP, the researcher suspects that the goals of the biology course are not being achieved. The instruments currently used in the biology course at

BUSCEP do not assess students' skills in manipulating equipment, observing, organizing and performing an investigation efficiently. In addition, it appears that students continue to have problems performing such skills after finishing the course.

3. AIMS OF RESEARCH

The aims of this project were to evaluate a major section of the biology course at BUSCEP to determine whether the goals of the section were being achieved. The section evaluated was the practical component of the cytology section.

4. RESEARCH QUESTIONS

The main research question was:

Are the goals of the practical component of the cytology section of the biology course at BUSCEP being achieved?

The four sub-questions were:

- Can the students recognize the parts of the light microscope?
- Can the students operate a light microscope correctly and efficiently?
- Can the students represent accurately what they see under the microscope?
- Can the students prepare a wet mount slide?

5. METHODS

In order to ascertain whether the goals of the practical component of the cytology section of the biology course at BUSCEP were being achieved, an absolute evaluation as opposed to a relative evaluation was conducted (Stake, 1967, 523).

I selected this type of evaluation to determine whether the intents (stated goals) of the curriculum were consistent with outcomes of the course (students' performance).

According to Stake (1967), absolute standards comprise three levels, namely, antecedents, transactions and outcomes.

- i. An antecedent is any condition existing prior to teaching and learning which may relate to outcome.
- ii. Transactions are the countless engagements which comprise the process of education. They include interactions between students with teacher, student with student, author with reader, and parent with counsellor.
- iii. Outcomes include the abilities, achievements, attitudes, and aspirations of students resulting from an educational experience.

In an absolute evaluation, before making a judgement, the evaluator determines whether or not each stated standard (antecedents, transactions, outcomes) is met. The judging act itself is deciding which set of standards to heed.

In a relative evaluation, the standards of one program are compared with the standards of other programs. As all the biology students do the BUSCEP course and there is no parallel program with which to compare, a relative evaluation was inappropriate for this study.

5.1 INSTRUMENTS

Two instruments, namely, a written practical test and an observation schedule were developed and administered by the researcher. The written practical test determined whether the students had *knowledge* of the parts of the microscope and their functions, and whether they *understood* how to use the microscope.

The observation schedule took the form of two checklists. Each checklist recorded

predetermined categories of skills. The first checklist focussed on skills related to the use of the microscope. The second checklist focussed on skills related to the preparation of a wet mount slide. The checklists indicated the presence or absence of the observed skill and provided feedback to the researcher as to which skills had been effectively mastered.

The instruments traditionally used in biology course at BUSCEP are written laboratory reports and paper-and-pencil tests. These instruments do not test the students' *understanding* of content nor the skills of making slides and manipulating the microscope. They test the memorization of content.

In addition, field notes were generated by open observation. This open observation occurred during one tutorial per week and all the laboratory practicals. It was expected that this open observation generated worthwhile data in the form of field notes which were then written during and after each observation. Field notes were data obtained in the setting by direct observation while the observer was in the field. They described in detail the setting and activities of students. Both anticipated and unanticipated outcomes were recorded.

5.2 SAMPLE

At BUSCEP there are currently four classes registered for the biology course. The students of these classes are drawn from several secondary schools and have varying levels of practical skills. Two classes of 41 students in total were involved in this study. The teacher of this class was an experienced teacher from the Netherlands. He had worked at BUSCEP since 1990 and was responsible for the subject biology. He developed the teacher-guide and student-guide that were used by all staff and students doing the course. It included both the theoretical and practical components of the course. The goals for each component were clearly stated in the guides. I selected this

teacher because I regarded him as the most experienced and successful teacher at BUSCEP. If goals were not achieved when he was teaching, one can be confident that they would not be generally achieved in the course.

5.3 VALIDITY

To consider the validity of the evaluation instruments, a colleague from BUSCEP, and experts in biology education at the University of the Witwatersrand were solicited to make their judgement on the instruments. They judged whether the instruments developed for this study, firstly, covered all goals of the cytology section as stipulated in the laboratory manual, and secondly tested what they claimed to test. A list of propositional knowledge statements and propositional skill statements representing what is required by first year Biology students completing a practical component of the BUSCEP Course was drawn up by the researcher. This provided the validators with a list of criteria against which to judge the face validity of the instruments.

The students were taught in Portuguese and the instruments were developed in English and were translated into Portuguese. A bilingual co-supervisor at the University of the Witwatersrand checked the instruments to validate their translation.

5.4 PILOT STUDY

A pilot study was conducted with 105 first year students in the College of Science programme at the University of the Witwatersrand in February 1997. The college students were seen to share certain characteristics with the BUSCEP students. However, conducting a comparative study would mean that the researcher had to compare the curriculum of the College of Science Students with the curriculum of the BUSCEP Students (see section 5 of this Chapter). Adding to this, the purpose of using the College of Science Students for this phase was to determine whether the

instruments were appropriate and unambiguous. Since the goals during the four first weeks of practicals are similar. Students learn how to operate a light compound microscope and to prepare wet mount slides. The pilot study helped to improve the validity and reliability of the instruments.

5.5 THE MAIN STUDY

The main study was conducted by the researcher in the period of August to September 1997. The four-week cytology section, involved two one-hour tutorials per week, and one three-hour laboratory practical per week. The structured observation schedules (checklists) were administered during certain practicals. Predetermined practical skills were observed. The checklists were used to record predetermined categories of skills and the presence or absence of the observed skill. The checklists were administered: firstly, when the students had to examine microscope slides under low, medium and high power magnification of the microscope, and secondly, when the students had to prepare their own temporary wet mount slides.

The written practical test was administered after the section on cytology had been taught. This instrument covered the parts and functions of the compound light microscope. The teacher was not aware of the content of the test prior to it being administered.

5.6 ANALYSIS OF RESULTS

Three types of data were generated by this study:

- 1) Raw data from the structured observation schedules (two checklists) were analysed to reveal the number of students who successfully carried out a particular skill. These data were recorded in tables.
- 2) The field notes generated by the open observation were analysed in order to

determine trends and common themes, and if appropriate, students' quotations were used.

3) The results of the written practical test were recorded in tables and bar charts, indicating the percentages of students who passed each question.

6. DELINEATION OF THE STUDY

In order to limit the scope of the research, only the practical component of the major section of the biology course at BUSCEP was evaluated to determine whether the stated goals of the course were being achieved. It would have been impractical to attempt to evaluate the entire BUSCEP biology course within the scope of this study. The section of the course which was selected considered large enough to give an indication of the success of the entire course. The selection of the 'cytology' section was based on its centrality to the study of biology in general and the biology course at BUSCEP specifically. It was believed that students who could not use the microscope effectively, would be seriously affected in their subsequent biology studies.

7. IMPORTANCE OF STUDY

BUSCEP, as a Basic Science Department within the faculty of Science, is an important initiative involving both the UEM and VUA, a considerable number of staff from different faculties, and sizeable budget. It has an important role to play in preparing students for their tertiary science education. It was therefore vital to ascertain whether the goals of BUSCEP were being achieved. This study, it was hoped, would be the first step in the development and improvement of the biology course at BUSCEP.

CHAPTER 2

LITERATURE REVIEW

1. INTRODUCTION

A literature review enables the researcher to deal with many aspects concerning the problem to be investigated. It is crucial that the researchers learn from previous studies, methods of how to find solutions to the research problem at hand.

The literature review aimed to:

- explore the role of practical work illustrating the importance of the inquiry methods in teaching laboratory activities, identifying the contribution of the meaningful learning in the process of learning;
- examine the issues concerning the strategies for teaching practical work;
- identify the importance of the acquisition of the microscope skills;
- illustrate the several strategies for assessment of practical work showing the advantages and disadvantages of the available methods of assessment and the importance of the assessment of microscope skills.

2. THE ROLE OF PRACTICAL WORK

Due to the influence of many curriculum development projects undertaken in the sciences during the 1960s and 1970s, practical work is currently accepted worldwide as an integral part of science education, at all levels (Kempa, 1987). However, Levinson (1994) points that the laboratory is the most favourable place for science teaching. Only in that way the young children will be in contact with the real world of science, rather than being always confronted with the natural phenomena in an abstract way in the classroom.

According to Hofstein & Lunetta (1982), laboratory activities are important in promoting practical comprehension of certain aspects of the nature of science. Also, they improve intellectual and conceptual development, as well as contribute to the development of positive attitudes towards science. The same authors see the process of developing abilities in problem solving for being a crucial element of the laboratory activities. There is an agreement between science educators about the importance and the function of practical work in the laboratory or field. However, opinions concerning the role of practical work are divergent (Tamir et al 1992). Tamir et al (1992) states that the practical work must be seen as the study of natural phenomena through observation and experiences to be carried on in the laboratory or in the field. Similarly, Kapteijn (1987) argues that we do practical work in order to study phenomena, not to study concepts. By studying phenomena students should be helped to develop concepts. This idea emphasises the fact that the examination of the concepts through laboratory activities can contribute for the development of the biological concepts.

Meanwhile, Tamir et al (1992) state that the role of the laboratory during the science curriculum reforms of the 1960s, was not only centred on verification and demonstration, but also, on science the learning process. This process includes: formulating hypotheses, collecting and recording data, organizing and interpreting the findings and formulating conclusions and generalizations. In that way the practical work must be seen as a means for providing opportunities for acquiring direct experience.

(Mech, 1990) believes that practical work consists of physical and intellectual abilities, which differ in some extent from the non- practical work. The actual performance of the practical abilities requires that the learners be directly involved because these abilities cannot be acquired only through observation and teacher demonstration. Tamir et al (1992) names this process which involves the acquisition of practical abilities in the context of actual laboratory investigation or field setting, the practical

mode. That is, practical work is a means by which this mode can be developed and practised. In addition, Tamir (1983) made more clearly the meaning of practical mode by stating that practical mode is a particular mode of thought and action in which reasoning, planning, problem solving, explaining interacts with manipulations, observations and other psycho-motor activities. Adding to this, Tamir et al (1992) points out three fundamental reasons for doing practical work: a) the laboratory is important in providing concrete, direct experience; b) the laboratory promotes the use of scientific methods, and c) the laboratory is a means for promoting positive attitudes towards science. In addition, Tamir et al (1992) outline that practical work has five fundamental objectives in science as follows: skills, concepts, cognitive abilities, understanding the nature of science, and attitude.

However, according to Hodson (1992), the poor conditions of designing an experiment, for example, small group size, lack of an adequate control of relevant variables and the use of inappropriate test instruments have contributed to the inefficacy of practical work. He adds that such difficulties can contribute negatively to learning outcomes, particularly to comprehension of scientific concepts and acquisition of positive attitudes towards science.

2.1 INQUIRY METHODS

According to Tamir et al (1992), the use of inquiry methods in teaching laboratory activities contributes to the students' progress in science. Inquiry methods mean that the pupils have an opportunity to discover new information for themselves when they are doing scientific activities. In doing so, pupils are required to use their knowledge of concepts, principles, theories, and laws together to construct new explanations concerning the natural objects and events (Rutherford & Ahlgren, 1990). Meanwhile, Trowbridge & Bybee (1990) support the idea that by giving students the freedom to inquire, and create and discover new information in order to solve novel problems science

laboratory can be helpful in providing more cognitive involvement and improving the thinking ability. Similarly, German et al (1996) argue that through the practice of inquiry, students acquire knowledge in a more meaningful way. In addition, they suggest that the following categories of skills should be considered during laboratory activities: formulating relevant questions, planning experiments, conducting systematic observations, interpreting and analysing data, drawing conclusions, communicating, and coordinating and implementing a full investigation. It is important to clarify the skills to be learned and the curriculum developers must take care in designing special learning materials to teach students through inquiry methods (Fiedler & Tamir 1986 and Bound et al 1986). In addition, German (1991) outlines that the provision of biology inquiry activities is useful because it helps students solve problems in a methodical way using science process skills. These skills include the identification of the problem, development of hypotheses, identification of variables, design of experiments for testing hypotheses, collection of relevant data from the experiment, transformation of data into useful tables and graphs, drawing of conclusions from the obtained data. The same author argues that it is important to take into account the background knowledge that students already possess because the problem to be solved, possible hypotheses, relevant variables, design of the experiment and conclusions are dependent on that background knowledge.

Tamir (1983) points out some evidence of the effects of the inquiry methods on students' learning and attitudes in the U. S. He says that some studies reported positive benefits while other studies reported that the inquiry method is not an adequate way of teaching science. For example, the new curricula illustrated positive impacts on the student performance in the U. S. for 17 out of 18 performance criteria. Tamir (1983) lists some of the performance criteria as follows: a) general achievement; b) attitudes towards science; c) process skills; d) problem solving; and e) creativity. The effects of the inquiry were great for biology, and medium and poor for earth science and chemistry respectively.

However, Igelsrud (1988), claims that despite the importance of the inquiry approach in illustrating or allowing the student to discover a biological concept, the inquiry approach fails to provide the necessary experiences needed to develop problem solving and thinking skills. He adds that there is a need for devising appropriate curricula material to teach these important skills. In addition, Hofstein & Lunetta (1982) argue that laboratory instruction can play an important role in achieving goals in the cognitive, practical and affective areas.

2.2 MEANINGFUL LEARNING

Lowe (1993) believe on the theory described by Ausubel which emphasises that the process of learning will only be meaningful if a new concept or idea to be learned is connected with success by the learner into the existing system of prior knowledge that the learners already have. In addition, Sanders (1988) points out that inquiry-based practical work can help the learner to make linkage between a new concept or idea and the existing prior knowledge. If this linkage does not occur, the learning process will result in rote-learning and memorization of the concepts. In order to make this process work it is important to re-organise and expand what is already known and what skill is needed to be learnt. Also, it is important to provide appropriate conditions for meaningful learning such as: availability of appropriate materials, disposition of the students to relate prior ideas to the new ideas, and preconceptions which allow the student to act on this disposition (Kirschner et al, 1988). The above mentioned conditions for meaningful learning are also applied to practical work. In order to facilitate the process of meaningful learning, it is important that the learner be taught first the component concept. Thus, when confronted with a problem which needs many concepts, the learners will be able to cope with them (Aho et al, 1993). Similarly, Hodson & Reid (1988) argue in favour of a learning experience in which the consideration of the prior theories and the exploration of the existing ideas can contribute for the effectiveness of practical investigation. They suggest that a pupil

needs to be equipped with an adequate theoretical understanding. Only in that way will he/she be able to make appropriate observations. It is important to devise a means of establishing the relationship between the two components, theoretical and practical, in the process of teaching biology. In doing so, practical work can contribute to promoting meaningful learning.

However, in spite of claims about the effect of practical work on improving learning, several authors claim that practical work does not always appear to promote meaningful learning (Head, 1982; Novak, 1984; West & Pines, 1985). In addition, Decker and Fraser (1989) claim that the theoretical and practical components of teaching biology cannot be separated.

3. STRATEGIES FOR TEACHING PRACTICAL WORK

According to Beyer & Charlton (1986), the simple exposure of the students to skill does not help them to acquire this skill. They also need frequently and alternating practice in order to use the skill and this process must be accompanied by an instructive guidance and immediate feedback. Beyer & Charlton (1986) mentions two types of strategies to improve the teaching and learning of practical skills, namely, strategies for introducing a skill and strategies for guided practice.

In addition, McCall et al (1983) grouped the practical skills into six categories: a) following instructions; b) observational skills; c) measurement skills; d) manipulative skills; e) procedural skills and; f) recording skills. Similarly, Sanders (1985) grouped skills required by a biology student into eight categories: a) language skills; b) practical skills; c) communication skills; d) learning skills (how to gather information); e) recording skills (how to store information); f) data processing skills (how to analyse and apply data) and g) conceptual thinking skills. According to Johnstone & Wham (1982), the current practice of practical work is

hampered through a high information situation in which the working memory is overloaded with arrival data. Students are frequently provided with new information and they are required to recall such information during each practical session. The information is for example, written instructions, verbal instructions, new manipulative skills, unfamiliar or unnecessary complex labelling of reagents. The same authors argue that this kind of information may lead to a state of an unstable overload. They suggest that in order to reduce this process of "noise", it is important to improve teaching strategies by considering the following aspects:

1. Give the students a clear statement of the point of the experiment;
2. Suppress the noise by stating clearly what is preliminary, peripheral and preparatory;
3. Redesign the experiment; and
4. Teach important skills, rather than trying to teach manipulative or interpretative skills simultaneously.

4. MICROSCOPE SKILLS

One of the most important instruments of a biologist in the process of teaching is the microscope. According to Dekker & Fraser (1989) the use of the light microscope requires that students concentrate their learning on manipulative skills and on practical skills. For that reason, there is a need to train the students adequately to be able to use a microscope effectively. This process is concerned with the acquisition of many manipulative skills. In addition, the same authors point out that effective use of the microscope contributes to the development of other skills and abilities, such as: preparing tissue cultures, cutting thin sections, mounting sections to be examined, drawing objects as seen under the microscope, labelling drawings, associating certain sections with specific functions, and executing oil immersion techniques. Mech (1990) believes that the process of teaching/learning microscope skills using the inquiry method allows students to understand how learning occurs, to concentrate on the strategies which allow them to discover new information. In order to demonstrate the

effectiveness of the inquiry method to teach microscope (Mech, 1990) conducted a study in south African schools. She found that the biology pupils who were taught to use a microscope by an inquiry approach, were significantly better at using microscope than a group taught using a traditional illustrative method, and that they performed significantly well on a test which observed their understanding on the use of the microscope.

Kaptein (1987) lists five fundamental groups of skills needed to use the microscope: a) how to fix the slide; b) how to move the slide; c) how to focus; d) how to adjust the light and e) how to interpret the object. However, she states that in order to acquire these skills associated with the use of the microscope much repetition is required. Eventually, this results in a combination of the information in something more general.

5. STRATEGIES FOR ASSESSMENT OF PRACTICAL WORK

5.1 INTRODUCTION

There is a growing concern worldwide about the teachers' assessment methods used for evaluating laboratory activities. Previous research indicates there is little doubt that teachers' assessment procedures influence how students apply their knowledge through practical work (Bates, 1978; Hofstein and Lunetta, 1982; Johnstone & Wham, 1982; Fuller & Heyneman, 1989; Tobin & Gallagher, 1987; Wilson & Stensvold, 1991). In addition, Doran (1978) has said that the inadequacy in the measurement of science process skills appears as result of the non existence of an appropriate conceptual framework for assessment procedures. Consequently the tests are not reliable.

Evidence was provided by Mayer & Richmond (1982) that evaluation in science tends to focus more in the measurement of content knowledge items. Their study showed that different instruments were found for different levels: 119 instruments assessed the level of knowledge, 32 assessed the level of achievement in skills, and 25 which

assessed affective objectives. Also, this came later, as a consequence of inquiry-based curricula in an attempt to assess the student's ability to apply science process skills (Mayer & Richmond, 1982). According to Cronbach (1963) the evaluation has been concentrated upon one process: the preparation of a paper-pencil-and-achievement tests for assessing scores to individual students. In addition to paper-and-pencil achievement tests, evaluation would be more effective if it also includes assessment of how the course content is being taught and whether the goals for teaching the course are being achieved. Doing so, the comprehensive evaluation may be useful in helping to know whether or not effective teaching is occurring. Cronbach (1963) argues that if evaluation is carried out in the service of course improvement, the chief aim is to ascertain what effects the course has, i.e. what changes it produces in students. The greatest service evaluation can perform is to identify aspects of the course where revision is desirable. Those responsible for developing a course would like to present evidence that their course is effective.

Quisenberry (1982) states that if laboratory activities are considered to be essential, then it is important to devise appropriate assessment procedures to directly assess the achievement of stated goals or skills. However, Quisenberry (1982) cautions that several limitations in designing an assessment procedure for practical work should be considered. These limitations can be: apparatus available, space requirements for students; the amount of time to be scheduled for the assessment; the task grading and the procedures to be used in administering the test. By contrast, Swain (1985) in Mech (1990, 20) claims that an underlying structure linking the assessment of students' understanding in a laboratory to the inquiry nature of science has not been developed. He says that an assessment model should match the inquiry nature of a subject and not merely the curricular materials. Furthermore, Fairbrother (1986) also, appraises critically the practice of assessment in the course. He elucidates that assessment is principally used to qualify the product of the single mark performed by the students. Tomlinson (1979) reported that in Nuffield Chemistry, as with other Examinations

Boards, the following skills/abilities, are assessed and proportion of the total mark associated with each skill set alongside it:

- skill in observation: 25%
- ability to interpret observation: 15%
- ability to plan experiments: 10%
- skill in manipulation: 30%
- attitudes to practical work: 20%

5.2 AVAILABLE METHODS OF ASSESSMENT

Van de Berg & Giddings (1992) and Tamir et al (1992) grouped the assessment procedures of the laboratory activities into four categories:

1. Written laboratory reports
2. Paper-and-pencil tests
3. Manipulative skills laboratory test
4. Continuous observation using observation schedules.

1. Written laboratory reports: are one of the common assessment methods traditionally used. According to Van de Berg & Giddings (1992) this kind of assessment method can hamper the evaluation. Moreover, the written laboratory reports do not always provide direct information about students' skills in manipulating equipment, observing, organizing and performing investigation efficiently. Sole dependence on laboratory reports in evaluating laboratory activities can lead students to copy from one another or to invent data.

2. Paper-and-pencil test items: designed to assess knowledge of the techniques and principles underlying laboratory procedures can be prepared, although this is often time-consuming. Test items also can assess student skills in planning, design, analysis and application phases of laboratory activities (Van de Berg & Giddings, 1992). Nevertheless, written test items should not be used exclusively as the basis for

evaluation. For example, students can be asked to read a temperature or a length from scale printed on the test, but their ability to do so with real equipment might involve other skills not measured on the written test. In addition, Tamir (1975) mentions six process skills which must be integrated in an assessment model according to the assessment of performance Unit in Britain. The six process skills were then grouped into two categories: a) skills with practical basis and b) skills with theoretical basis. The practical based skills are: apparatuses and instruments, observation and symbolic representations such as graphs and histograms. The theoretical based skills are interpretation and application of theoretical information previously learned, investigation design and investigation performance. Furthermore, Tamir (1975) states that due to the nature of the practical skills it is possible that these be assessed during the actual performance of students in a laboratory while the theoretical based skills can be assessed through a paper-and pencil test items. In addition, Tamir et al (1992) stress that the general tendency in the U. S. and elsewhere has been to test for most of laboratory objectives by paper-and-pencil tests.

3. Manipulative skill laboratory tests: Students involved in a particular experiment can be assessed during the actual performance of a practical test. Students are required to perform experimental work according to well-defined instructions, usually involving a relatively simple concept, so that the chief purpose of the exercise can be to examine the level of manipulative skill. Van de Berg & Giddings (1992) laid down four categories of manipulative skills which can form the basis for observational assessment. This kind of assessment is important to assess acquisition of manipulative skills, observational abilities and more complex problem-solving and process skills.

Van de Berg & Giddings (1992) breakdown the manipulative skill into four major groups: a) experimental technique; b) procedure; c) manual dexterity and d) orderliness. Birchall (1987) conducted a survey in order to ascertain whether American teachers were supporting the established criteria for assessment of practical skills or a formal

practical examination. The results showed that the teachers who participated in the study claimed that with the aid of guidance, it would be possible to use the established criteria for assessment. The use of the practical examinations changed dramatically the laboratory instruction in Israeli schools, which become more inquiry-oriented. Tamir et al (1992) argues that pupils were frequently found to be able to produce a reasonable plan in paper-and-pencil tests, but were quite unable to do in practice anything of what was planned. The same authors claim that it is not just a manipulative skill which makes a difference between theory and practice in problem solving, but the interaction of ideas with events as they take place.

4. Continuous observation using observation schedules: The use of a practical test has shown some limitation regarding to those experiments that can be readily administered to students in limited time. So restrictions of the scope and validity of such assessment are evident. According to Van de Berg & Giddings (1992) continuous assessment on several occasions throughout the year is necessary to adequately cover the range of tasks and techniques which comprise a total program of laboratory activity. Also, with a greater involvement in the continuous assessment of practical skills, the teacher is likely to develop a greater awareness of the scope and objectives of laboratory activity, as well as to help to identify students strengths and weaknesses that otherwise may not have been reflected in more traditional assessments. Similarly, Croll (1986) argues that the attempting of the systematic classroom observation is to arrive at descriptions of classrooms which are absolutely explicit in their purposes and which remove part of their subjectivity which occurs when individuals describe events. Systematic observation in a classroom is a research method which uses a system of highly structured observation procedures applied by trained observers in order to gather data on patterns of behaviour and interaction in a classroom. According to Guba et al (1981) the term observation, by most social scientists means participant observation and has become synonymous with field research, field work, or uncontrolled observation, participant and nonparticipant alike. So, he defines participant observation

as involving "a period of intense social interaction between researcher and subject in the milieu of the latter. During this period the data are unobtrusively and systematically gathered". Opposed to participant observation is the nonparticipant observation, the observer plays only the role of observer. In the participant observation, the subjects being observed may or may not be aware of the observer's role as observer.

Guba et al (1981) listed the following advantages of the observation techniques:

- make it possible to record behaviour and events as they occur.
- make it possible to build on both propositional and unstated knowledge.
- are well adapted to "maximize discovery and descriptions".
- enhance the observer's ability to understand complex situations.
- permit data collection in instances where other forms of communicating are impossible.
- allow at least some opportunity for study without the subject's active cooperation.

5.3 ASSESSMENT OF MICROSCOPE SKILLS

One area of practical work which is fundamental to the study of biology is the use of the microscope, one of the basic tools of the biologist. It is important for students to have knowledge and skills to carry out simple studies using the microscope as an investigative tool. It takes time and effort on the part of the educator and learner to successfully develop the range of skills required for the effective use of the microscope. According to Barker (1981) while students are often able to write down steps involved in the use of a microscope, many are unable to implement them physically. So it is important to assess the laboratory activities and skills in order to determine whether the students have in fact mastered these skills. Barker (1981) found in his research carried out in Britain, some empirical evidence which reports that several biologists conclude their first degrees without receiving a thorough training concerning the use of a microscope in the correct way. He outlines that of twenty-three post graduate biology students on teacher education courses in Britain, only one student successfully

performed the task of how to set up a microscope accurately.

Mech (1990) discusses the point made by Mitchel & Kellington (1979) that providing adequate assessment procedures for administration and monitoring of tests of microscope skills is difficult. Also, the same authors argue that to observe each pupil individually takes more time and it would be better to provide an exercise in which certain observations can be made only if the correct procedures are carried out, without necessarily requiring continuous observation by the teacher. In addition, they caution that there is a great variety in types of microscope which are available, and different microscopes require different operations. Important to be considered is that no matter what microscope design is familiar to pupils, they should be able to use their own microscope successfully.

Issues concerned with assessment of practical skills were analysed and correspondent tests assessing various practical skills were developed, such that pupils were required to locate and focus on a specimen using a microscope at different focal depths. For that reason, it was obvious that there is a need of providing teachers with adequate assessment instruments and procedures which can contribute to the improvement of students' performance at their best levels and which can grant feedback in order to elevate the quality of students' learning (McCall et al, 1983). Adding to this, McCall et al (1983) argue that also there is a need for integrating assessment procedures and instructions drawing an analogy between cognitive assessment and the classroom use of short objective questions. McCall et al (1983) points out some evidence from the TAPS practical test items which presents the pupil with a task requiring a few minutes to complete. Each item is designed to use a particular skill and the other skill elements are embodied in that task. They used a checklist to test success/failure in performance on practical test items. McCall et al (1983) suggest that if possible, the item should be constructed so that a simple end-check of the product of the task enables one to conclude that the skill used in obtaining the achievement was correct.

CHAPTER 3

RESEARCH METHODS

1. INTRODUCTION

This chapter deals with the research methods used in the study. It incorporates the following:

- the development of the instruments;
- the selection of the sample;
- the validation of the instruments;
- the pilot study;
- the main study;
- the analysis of the results.

The aim of this research was to evaluate a major section of the biology course at BUSCEP to determine whether the goals of the section were being achieved. The section evaluated was the practical component of the cytology section. It was therefore necessary to conduct an absolute evaluation as opposed to a relative evaluation (Stake 1967). The reason for selecting this type of evaluation is outlined in section 5 of Chapter I.

2. DEVELOPMENT OF THE INSTRUMENTS

In order to achieve the aims of this study, two instruments, viz. a written practical test and an observation schedule were developed and administered by the researcher. These instruments are briefly described below:

2.1 THE WRITTEN PRACTICAL TEST

The written practical test was designed with the objective of determining whether students had *knowledge* of the parts of the microscope and their functions and; whether they *understood* how to use the microscope. This test involved forty-one first year students from the BUSCEP biology course. A copy of the test is included in Appendix 1.

The written practical test comprised two Sections: section A and section B.

- Section A tested whether the students had mastered the knowledge of the parts of the microscope and their functions, secondly, whether the students understood how to use the microscope.
- Section B tested whether the students had knowledge about focussing at different focal depths in order to view the whole specimen. Additionally, this section also tested whether the students could :
 - locate and focus on the specimen;
 - draw accurately what they have seen under high power magnification;
 - locate and focus on the specimen at different focal depths.

Section B required the use of prepared slides which were considered part of this instrument. The instructions on how the slides were prepared are presented in Appendix 9.

The written practical test was divided into two sessions. This was carried out particularly because the biology laboratory seats 32 students per session. These students were divided into 16 groups of 2 students each. Since the students sit too closely each other under normal circumstances, conducting the written practical test in two sessions limited the possibility of note sharing between the students.

2.2 THE OBSERVATION SCHEDULE

The second instrument, an observation schedule, comprised two different checklists and the use of a prepared slide which was considered part of this instrument (see Appendix 9). Each checklist recorded predetermined categories of skills.

- The first checklist was designed to determine whether the students had mastered the *necessary skills needed to operate a microscope* in the correct manner, viz. to locate and focus on a specimen using low, medium and high power magnification, sequentially.
- The second checklist was designed to test whether the students could master the *skills needed to prepare a wet mount slide*.

Both checklists were administered to 20 and 21 first year students of the biology course at BUSCEP, respectively. The two checklists are included in Appendices 2 and 3.

In addition, field notes were generated by open, unstructured observation (see section 5.1 of the Chapter I). The purpose of the observation was to investigate:

- how the information was presented in tutorials and practicals;
- how often the students are assisted in handling the microscope;
- how the instructions are given to the students (individually or in a group);
- whether students read the instructions in the practical guide while they work;
- whether students work independently;
- whether students ask special questions concerning the content;
- whether students take time reading through all information in the practical guide.

3. SELECTION OF THE SAMPLE

In order to achieve the aims of this research, two classes of forty-one first year biology students from BUSCEP at Universidade Eduardo Mondlane were used. The students were selected from the four classes registered for the biology course. These students were drawn from several secondary schools and having a wide range of practical abilities. The reason for using this sample has already been outlined in section 5.2 of Chapter I.

The written practical test was administered to all forty-one students. The observation schedules (checklists) was administered to 20 and 21 students, respectively that is, checklist I tested 20 students and checklist II tested 21 students. Open, unstructured observation focussed on all students.

4. VALIDATION OF THE INSTRUMENTS

According to Mulder (1993), validity refers to the degree to which a test succeeds in measuring what it claims to measure. In this study, of particular interest, was face validity. Face validity is when the instrument shows at first impression what it purports to measure (Sanders & Mokuku, 1994). Therefore, the evaluation instruments were validated.

A list of propositional knowledge and skill statements was drawn up by the researcher. For this study, propositional knowledge and skill statements are proposed scientific statements. They represent the requirements of first year practical component of the cytology section of the biology students of the BUSCEP Course. In this course students are expected to comprehend how the microscope operates, prepare a wet mount slide, know the parts and functions of the compound microscope. Appendix 4 shows the list of propositional statements used.

The propositional statements were drawn up according to the aims stated in the Basic Science Department first year Biology practical guide of the BUSCEP at Universidade Eduardo Mondlane in Maputo. The propositional knowledge and skill statements provided the validators with a list of criteria against which to judge face validity of the instruments. Instruments were validated by five teachers experienced in biology education. This teacher compliment comprised 4 teachers from the University of the Witwatersrand and one from Universidade Eduardo Mondlane in Maputo. Based on this feedback, some questions in the written practical test (section A) were eliminated and others amended. Appendix 1 shows the revised version of the written practical test.

In addition, the validators, also commented on the questions in section B. It was therefore emphasised that the question for slide A should require students to draw the specimen "accurately", and not "exactly" as it was previously stated. Since the students had demonstrated a tendency to locate and focus only on one or two sets of symbols it was more appropriate that they were instructed to "locate all the words" on slide B be located and write them down on the space provided. The observation schedule (checklists) was also altered with respect to the correct sequence of the steps needed, to prepare a wet mount slide and the use of the microscope. Appendix 2 and 3 show the revised version of the checklists.

Since the students were taught in Portuguese, it was necessary to translate the instruments developed in English into Portuguese. A bilingual co-supervisor from the College of Science at University of the Witwatersrand was consulted to examine the instruments to validate their translation. The copies of the translated instruments are presented in Appendices 5, 6 and 7.

5. THE PILOT STUDY

The aim of the study was to determine whether the instruments developed for the main study, were appropriate and unambiguous. The survey included one hundred and five first year biology students from the College of Science program at University of the Witwatersrand. The College students shared similarities with the BUSCEP students used in the main study. This study helped to improve the validity and reliability of the instruments, and was performed after the students had been taught how to handle the microscope correctly.

5.1 THE WRITTEN PRACTICAL TEST

The written practical test comprised two sections, Section A and Section B.

Since the microscope slides for administering section B were not ready, section A was administered first.

Students were allocated 20 minutes to complete section A of the written practical test. This section was administered to all 105 students.

Section B was administered 2 weeks later after the slides were prepared. A copy describing the preparation of the slides is outlined in Appendix 8. Section B involved only sixteen students.

Slides prepared by the researcher were part of section B.

Appendix 8 illustrates the instructions for preparation of the slides used.

Different sets of slides were used for the drawing test and the focal depth test. For the drawing test, students were provided with three types of slides:

- Slide A contained a long word (electronic) photographed and printed on a white background.
- Slide B contained a long word (electronic) photographed and printed on a blue background.
- Slide C contained a short word (dog) photographed and printed on a white background.

This enabled the researcher to decide which slides would be most appropriate to use in the main study.

Students were required to locate and focus on the specimens mounted on each of the three slides and draw accurately what they observed under high power. Generally, students spent approximately 15 minutes on the three slides.

For the focal depth test, slides containing three different symbols (\$, + and &) were mounted at different focal depths and administered to various first year students of the College of Science. The time required was approximately five minutes per student. The preparation of the slides is described in Appendix 8.

5.2 CHECKLISTS

Sixteen students were tested using the first checklist to test the effective use of the microscope. The description of the slides used for this checklist is included in Appendix 8.

5.3 RESULTS OF THE PILOT STUDY

Analysis of the results of the pilot study revealed that in the written practical test, some questions appeared ambiguous as was clearly apparent from the responses. It was therefore necessary to reformulate some questions. Further, some questions were found to be irrelevant, and thus taken out of the test. The written practical test not only

suffered changes in its questions but in addition, one question of testing whether the students had knowledge of the parts of the microscope, was added. The final version of the modified written practical test is included in Appendix 1.

In both checklists, there were some changes with respect to the correct sequence of the steps required to locate and focus on the specimen under low, medium and high power. Additionally, changes were made to the procedures on how to assess the wet mount slides prepared by the students. These changes were a result of the comments from validators. The final checklists are presented in Appendices 2 and 3.

There was some modification in the preparation of slides of the specimens to be used. Since the students were drawing the same symbol differently, it was more appropriate to use words in the main study instead of the symbols. The way in which symbols were organized is described in Appendix 8 and the words used for the final version are included in Appendix 9.

The long word (electronic) photographed and printed on a white background was the decided choice. The reasons for this decision are:

- When the word was reduced photographically, the transparency came out as a black letters printed on a slightly blue background. When this word was cut out and placed on a slide, the blue square was very easy to locate. This problem had to be corrected.
- When a word was photographically reduced it became so small that it could not be read with the naked eye - this meant that a short word (such as "dog") was so tiny as to be practically invisible (a dot). A long word could also not be read with the naked eye yet was easier to locate under low power.

6. THE MAIN STUDY

Two instruments were used in the main study, i.e. a written practical test and an observation schedule (checklists). Students were familiar with the section on Cytology when the written practical test was administered. The structured observation schedule (checklists) was administered during certain practicals. The procedure that was followed to implement the instruments is described below. Copies of the written practical test and observation schedule (checklists) are presented in Appendices 1, 2 and 3.

6.1 WRITTEN PRACTICAL TEST

A microscope, two prepared slides, slide A and slide B, and the written practical test were placed at each bench before the students entered the laboratory. The written practical test was divided into two sections (Section A and Section B). As mentioned earlier, the biology laboratory seats 32 students per session. These students are divided into 16 groups of 2 students each. As a consequence of the students seating closely to each other, conducting the written practical test in 2 sessions limited the possibility of note sharing between the students. The students were given instructions to locate all the words mounted on each of the two slides, focus on the words, draw accurately what they observed under high power in slide A and write down all the words visible on slide B in the space provided.

Students were not aware of the correct number of words mounted on the slide B, because one of the requirements of the biology students is to be able to search a slide, at different focal depths to look for all available specimens. If the students were aware, they could have written down the words automatically without looking for them under the microscope.

Students were given instructions to write and draw all the words in the space provided

on the written practical test. No communication between students was allowed. The researcher collected the test immediately after the students had finished the test so as to deny the students any opportunity of comparing and consequently amending their drawings.

In order to assess if the students had drawn as accurately as possible what they viewed under high power, a circle was drawn on a sheet of paper indicating the field of view of the microscope. Students were required to draw what they viewed under high power in the circle. To evaluate whether they drew what they had viewed the drawings had to fulfil certain criteria:

- Under high power the image fills more of the field of view than it does under low and medium power.
- Under high power it is not possible to view the whole specimen, only a proportion can be viewed.

6.2 CHECKLIST I

Students were provided with a microscope and a slide and were required to locate and focus on the specimen under low, medium and high power magnification. The microscope slide used, had one word (electronic) mounted at one focal depth. Each student was observed individually, to assess how he or she was performing the skills needed. Each step performed was ticked on the checklist by the researcher. This kind of assessment procedure was aimed at determining whether the students had mastered the skills needed to use the microscope correctly, i.e. in locating and focussing on the specimen. Each of the 14 skills was numbered sequentially on the checklist in order to enable the researcher to analyse the results obtained. Each student was given five minutes to locate and focus on the specimen in the correct sequence. This checklist is presented in Appendix 2.

6.3 CHECKLIST II

To assess whether the students performed the skills effectively in making a wet mount slide, the quality of the slide was examined and assessed according to the established criteria. Students were required to produce a wet mount slide of a leaf peel. The checklist in which the quality of the slide was assessed is presented in Appendix 3.

In order to avoid the deterioration of the slides; which can occur if slides are left too long after preparing; the 21 students involved in this checklist were divided into 3 groups of seven students each. Each of the 3 groups were given 5 minutes to prepare the slides and the researcher used the immediate 10 minutes thereafter to assess the slides. This was done consecutively for the 3 groups.

7. ANALYSIS OF RESULTS

Due to the nature of the data generated by the two instruments, i.e. a written practical test and observation schedule (checklists), a descriptive approach was used instead of a detailed statistical analysis.

The data obtained from the written practical test were recorded in tables and bar charts, showing the percentages of students who passed each question.

The raw data from the structured observation schedule (checklists) were analysed to reveal the number and percentages of students who successfully carried out a particular skill. These data were recorded in tables.

The field notes generated by the open observation were analysed in order to determine trends and common themes, and if appropriate, students' quotations were used.

CHAPTER 4

RESULTS AND DISCUSSION

1. INTRODUCTION

In this chapter I present and discuss the results obtained from the two instruments used in the main study. The aim of the main study was to evaluate the practical component of the cytology section of the biology course at BUSCEP to determine whether the goals of this section were being achieved. I attempted to answer the following research questions:

- Can the students recognize the parts of the light microscope?
- Can the students operate a light microscope correctly and efficiently?
- Can the students represent accurately what they see under the microscope?
- Can the students prepare a wet mount slide?

Several obstacles were encountered while carrying out the study. The national census in Mozambique, which involved university lecturers, resulted in the University semester commencing three weeks late. The course lecturer, therefore, had less time to complete the number of lessons (equivalent to 12 hours) allocated to the course being evaluated. In addition, one 3-hour laboratory session was not given due to a public holiday. The researcher, therefore, also had to rush the administration of the instruments. Extending the time would have been inappropriate, since the practical component evaluated occurred within the established 12 hours.

Observing all 41 students involved in the main study was not possible due to the constraints of time. Observations needed too much time and would have required extending the period of the study. Keeping in mind the setbacks that were mentioned in order to achieve the aims of this study, two instruments were used, namely a written practical test and two observation schedules (checklists).

In the written practical test:

Question 1 addressed the first research question: "Can the students recognize the parts of the light microscope".

Questions 2, 3, 4a, 4b, 4c, 5a, 5b, 5c, 6 and 7b addressed the second research question: "Can the student operate a light microscope correctly and efficiently".

Question 7a addressed the third research question: "Can the students represent accurately what they see under the microscope."

I will first present and discuss the results of the written practical test. Then I will present and discuss the results of the che

2. THE WRITTEN PRACTICAL TEST

The written practical test comprised two sections, A and Section B. Section A comprised five questions and section B comprised two questions. The instrument is presented in Appendix 1 and the results of the two sections are discussed individually.

2.1 SECTION A

In this section students were expected to show that:

- they had mastered the knowledge of the parts of the microscope and their functions;
- they *understood* how to use the microscope.

The percentages of students who passed each question are presented in Table 1. The maximum possible score for each question and the score obtained is also shown.

Table 1: Percentage scores of students for each question of the written practical test in Section A (50% is considered to be a pass mark). (n=41)

Question number	1	2	3	4a	4b	4c	5a	5b	5c
Max. Score	6	2	2	6	6	2	2	2	2
Obtained score									
6	22%	-	-	0%	0%	-	-	-	-
5.5	39%	-	-	0%	0%	-	-	-	-
5	22%	-	-	0%	0%	-	-	-	-
4.5	7%	-	-	0%	0%	-	-	-	-
4	7%	-	-	0%	5%	-	-	-	-
3.5	2%	-	-	0%	0%	-	-	-	-
3	0%	-	-	7%	2%	-	-	-	-
2	0%	22%	93%	37%	32%	24%	27%	22%	10%
1	0%	0%	0%	27%	17%	34%	12%	57%	56%
0	0%	78%	7%	29%	44%	42%	61%	20%	34%

Question 1: Can the students recognize the parts of a light microscope?

Only 22% of the students could recognize all 12 parts of a light microscope obtaining full marks. However, some students failed to recognize 1, 2, 3, 4 or 5 parts of the microscope (see Table 1).

The results show that all students could recognize at least half the parts of a light microscope. However, a certain percentage of students named some parts of the microscope incorrectly. For example, instead of the "clamp" (#3), 2% of the students named it the "hole in the stage", while three other students named it the "preparation". Instead of "a light source" (#6), 5% of the students named it the "condenser". Instead of "nose-piece" (#1), 10% of the students named it the "diaphragm". The reason some students did not recognize the light source might have been because the microscope diagram in the biology practical guide had a mirror instead of a "light source". This

error requires a correction, since the microscope used in BUSCEP consisted of light source. Students who did not recognize other parts of the microscope correctly, may have known the names but probably lacked the ability to associate the names with their respective parts.

The exposure of the students to the microscope 3 weeks before the written practical test was administered might have contributed to the students' high performance in this question. Additionally, observations made during practicals indicated that the students needed more detailed explanations by the lecturer and technician about the parts of the microscope and their functions. According to Mech (1990), it is important that students know all the parts of a light microscope. This would have enabled them to relate any part of the microscope to the function of that specific part and thus to understand subsequent questions concerning the use of the microscope.

Question 2: Do the students know how to move the microscope slide to keep the living organism in the field of vision?

Only 22% of the students could indicate the correct direction to move a slide in order to follow a moving organism scoring full marks (Table 1). The results showed that most of the students were unable to predict the direction that a microscope slide ought to have moved in order to keep an organism in the field of view. This was because students did not understand the principles of moving a microscope slide. The possible explanation is that students might have confused the moving of a fixed organism on a slide, and a living organism on a slide. If students were unclear about the principles of moving the slide they, therefore, would have difficulties in locating and focussing on the specimen. Students might have knowledge about the principles of moving a slide, but they lack understanding when it comes to moving a slide with a living organism. The reason for this was that students at BUSCEP learnt to move the microscope using only fixed organisms. It is important that examples with living organisms also be included in the practical guide. To understand the principles of moving microscope slides, students

need to be given more time to repeat the skill. Thus, with time, they will be able to acquire this skill. To support this idea, Beyer & Charlton (1986) argues that the simple exposure of the students to a particular skill to be learned does not help them to acquire this skill. It is important to provide them with a frequent and alternating practice in order to use the skill. This process must be accompanied by an informative guidance and immediate feedback.

Question 3: Do the students know how to calculate the magnification of an image viewed under the microscope?

In this question 93% of the students responded correctly obtaining full marks (Table 1). The results suggest that a vast majority of the students knew how to calculate the magnification having understood the principles of calculating magnification. The question only required students to recall the principles of calculating magnification. Therefore, students were required only to find out the magnification of the ocular lens and objective lens, which was given in the question. Another possible explanation is that students could link the concept "magnification" with the functions of the ocular lens and objective lens, which were repeatedly explained during the practicals. Thus, the results for this show that the students could do the task.

Question 4: Do the students know how to use the microscope to correct certain problems?

Question 4a: Can the students use the microscope to focus on the specimen?

None of the students obtained full marks to Question 4a (Table 1).

Examples of the students' responses include:

- one student replied that he would rotate the nose-piece to place the low power objective lens to locate the specimen, instead of "re-centering the specimen under medium power and then returning to higher power".

- another students' response was that there was a lack of sufficient water in the preparation, instead of "the organism is too big and the field of vision is too small and the whole specimen cannot be viewed".
- yet, another student wrote that: student lost the specimen by moving the fine focus adjustment knob, instead of "focussing the microscope with the fine focus adjustment knob to get the sharp image.

The results showed that students experienced many difficulties answering the question because the question required them to be more reflective instead of responding at the theoretical level. The question demanded that the students apply the knowledge already acquired about the use of a microscope in a concrete situation, thus solving certain problems rather than recalling the content. Students were also forced to think in order to make their responses to the questions meaningful. Furthermore, the lack of reading habit negatively influenced their understanding of the question. Observations made during practicals revealed that students displayed difficulties in reading and understanding the instructions in the practical guide. Therefore they needed extensive assistance from the lecturer and technician, in handling the microscope correctly, adjusting the light and centering the specimen in the field of vision.

Question 4b: Can the students use the microscope to see the details of the specimen when required?

None of the students obtained full marks for this question (Table 1).

Examples of students' responses to the question included:

- one students' response was that he/she moved the coarse and fine focus adjustment knobs without being aware, instead of "used an inappropriate light".
- another students' response was that he/she must add water or stain to the preparation instead of "making a new specimen using a thinner section".

- yet, another student wrote that the ocular lens was dirty instead of “specimen was viewed at low power.

The results showed that a large proportion of the students lacked understanding since this question, like Question 4a, required them to be more reflective, to discover ways to solve the problem (for more information see question 4a). The results of the observations made during practicals showed that students had problems in adjusting the light, using the coarse and fine focus adjustment knobs and centering the specimen. Thus, students appeared to have lost the specimen in their slides. Additionally, as in question 4a, students showed difficulties reading and understanding the instructions in the practical guide. As a result, they needed more assistance in handling the microscope correctly.

Question 4c: Can the students use the microscope to locate the specimen?

Only 24% of the students responded correctly to the question obtaining full marks (Table 1). The results suggest that most of the students did not understand the question, since this question required them to be more reflective to discover the solution to the problem as in questions 4a and 4b. (See question 4a for more information). Consequently, students gave the following responses to the question:

- one of the students wrote he had to move the preparation to the left and down instead of “placing the specimen right over the hole on the stage”. The justification of the action was: “ by moving the preparation to the left it will be possible to view the image moving up” instead of the “specimen is only visible if light can shine through it” (i.e. light only shines through the hole).
- one of the student, who gave an incomplete response, wrote as a justification of placing the specimen right over the hole on the stage that: “only so, it will be possible to observe the image of the object or to allow the dislocation [sic] of the object through the microscope slide”.

Evidence from the field observations made during practicals revealed that students had difficulties in reading and understanding the instructions in the practical guide and, they showed difficulties in centering the specimen. These shortcomings might have implications on the effective use of the microscope, viz. to locate and focus on the specimen. If the student cannot centre the specimen, difficulties in carrying out subsequent skills needed to operate a light microscope correctly and efficiently, will result.

The results indicated that most of the students did not *understand* the use of the microscope to correct certain problems. This was compounded by the fact that most students might not have the ability to relate the parts of the microscope with their specific functions. In addition, the lack of reading habit and the short time exposure for the completion of the section A of the written practical test may have hindered the students understanding of the questions. The questions required more effort by the students because more reading, thinking and answering needed to be done.

Question 5: Do the students know the procedures to use the microscope correctly?

Question 5a: Do the students know how to look through the ocular lens of the microscope?

Only 27% of the students gave an acceptable response to this question obtaining full marks (Table 1). The results showed that students who gave an incomplete response, could only indicate the correct alternative without being able to explain why. They might have done so by chance, or because they knew the correct response, but lacked the argument to explain why. For example:

- one student chose the correct alternative (ii). However, he explained his choice by stating that: "because in the ocular lens there is space only for one eye. Two eyes cannot be at the ocular lens simultaneously".

- another student, who scored 0 out of 2, choose the (i) instead of alternative (ii). The explanation was that: "one eye allows better observation, because the ocular has a very small lens".

The results suggest that most of the students (61%) did not understand the importance of keeping both eyes open by looking through the ocular. This implies that students with such problems will have difficulties in representing as accurately as possible what they observe under the microscope, since they do not know the procedures involved in using a microscope correctly. This misunderstanding may have arisen because this section was not clearly emphasized as important in the biology practical guide.

Question 5b: Do the students know how to take the microscope slide from the stage?

Only 22% of the students responded correctly to Question 5b obtaining full marks (Table 1). Like Question 5a, students with incomplete responses indicated only the correct alternative without justification. Similarly, they might have done so by chance, or because they knew the correct answer but lacked the argument to explain why. For example:

- one student chooses the correct alternative (i), but the explanation was unacceptable. He wrote: "the other answer is wrong because we must leave the microscope with the low power objective down" instead of "the object lens and slide can hit each other, damaging both".

The results show that the majority of the students have a weak understanding of the importance of taking the microscope slide off the microscope stage when the low power objective is in position. This implies that further clarifications of this section in the biology practical guide is required.

Question 5c: Do the students know how to use the both focus adjustment knobs?

Only 10% of the students gave complete response to this question obtaining full marks (Table 1). The results suggest that more than half of the students (56%) could only indicate the correct alternative without being able to give an explanation. Possibly, some students knew that when the high power objective was in position, focussing must be done with the fine focus adjustment knob. However they lacked an understanding of why this is so. Other students might have responded by chance since the question contained two alternatives.

- One student chose the correct alternative (ii) but could not explain why the other was wrong. He wrote: "the coarse focus adjustment knob is to lower down the microscope stage, moving away the object from an optic centre".
- another student chose the (i) alternative as correct instead of (ii). He explained that the other one was wrong because the "fine focus adjustment knob is only to reject the regulation of the image to turn it sharp".

The lack of understanding of the importance of using the fine focus adjustment knob when the high power is in position can negatively affect the correct and efficient use of the microscope. Evidence from the observations made during practicals revealed that students had problems in handling the microscope correctly, adjusting the light, using both focus adjustment knobs and centering the specimen and appeared to have lost the specimen in their slides. Therefore, students relied on extensive explanation by the lecturer and technician.

Several authors recognize the problems that arise in the use of the microscope to correct particular problems as in the procedures to use the microscope correctly. Students need more time to be trained adequately in order to understand the procedures of the use of the microscope. As emphasised by Kapteijn (1987), in order to acquire some fundamental skills students need more time to repeat such skill. Similarly, some empirical evidence has been reported which outlines that several biologists conclude

their first grade without receiving a thorough training concerning the use of a microscope in the correct way (Barker, 1981).

2.2 SECTION B

In this section, students were expected to show that they:

- had mastered the knowledge about focussing at different focal depths in order to view the whole specimen.
- could locate and focus on the specimen and accurately represent what they saw under high power magnification.
- could locate and focus on the specimens at different focal depths.

Table 2 shows the percentages of the students who passed each question. The maximum possible score for each question and the obtained score, is also shown.

Table 2: Percentage scores of students for each question of the written practical test in section B (50% is considered to be a pass mark). (n = 41)

Question number	6	7a	7b
Maximum score	2	2	6
Obtained score			
6	-	-	71%
4	-	-	10%
2	34%	61%	12%
1	0%	0%	0%
0	66%	39%	7%

Question 6: Do the students know how to focus at different focal depths to view the whole specimen?

Question 6 was designed to test whether the students had mastered the knowledge about focussing at different levels to view the whole specimen. The results showed that only few students (34%) could give the correct response to this question obtaining full marks (Table 2), indicating that most of the students have a very weak knowledge and understanding of focussing at different levels. Students who gave the correct response might have done so because they understood the concept "focal depth". Additionally, they could establish the relationship between the concept of "focussing at different levels", and the three-dimensional structure that the specimen often possesses. Students who responded incorrectly have a very weak understanding of focussing at different levels. Some of them chose the correct alternative by chance. In addition, students appear unable to interpret the diagram of the microscope thoroughly because it could help them to indicate the correct alternative.

Question 7a: Can the students locate and focus on the specimen representing accurately what they see under high power?

More than half of the students (61%) could locate and focus on the specimen, and accurately represent what they saw under high power magnification. They obtained full marks (Table 2). Thirty-nine percent of the students were unable to locate and focus on the specimen. Consequently, they could not accurately draw what they saw under high power magnification.

The results seem to indicate that a larger proportion of students have a good understanding on how to use the microscope to correctly locate and focus on the specimen. These students might have done better because they had the chance to recall some steps needed to locate and focus on the specimen, by implementing the knowledge that they already possessed about the use of the microscope.

Students who could not locate and focus on the specimen and represent what they saw under the microscope, might have experienced difficulties in setting up the microscope correctly and recording what they observed. Some of them had set up microscope correctly but were unable to observe the appropriate specimen. If students have difficulties accurately representing what they see under the microscope, this implies they have difficulties in interpreting what they observe (Mitchell & Kellington, 1979). The same authors recommended the following: "it would be of benefit to observe more closely the way in which they set up the microscope. Once they have identified individual difficulties, they would provide appropriate additional work before they continue the course".

Question 7b: Can the students locate and focus on the specimens mounted at different focal depths?

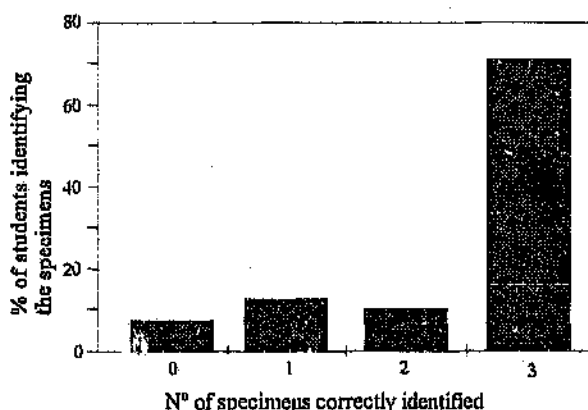


Figure 1: Percentages of the students correctly identifying the specimens on the slide B.

A vast majority of the students (71%) achieved the aim of Question 7b, which was to determine whether students could locate and focus on the specimens mounted at different focal depths (Figure 1) obtaining full marks (Table 2). The results suggest that most of the students could use the microscope correctly and efficiently. This

means that they knew how to find all the words on the slide B by carefully adjusting the fine focus adjustment knob, and therefore locate all the words mounted at different focal depths.

Meanwhile, the results of the section A did not negatively affect the students' performance in this question. In this question students had the chance to recall and repeat the skills necessary to use the microscope implementing them several times (Kapteijn, 1987).

Mech (1990) conducted a similar study in South African schools, with the aim of determining whether the pupils had mastered the physical skills involved in the effective use of a microscope. However, there are some differences in the way she prepared the slides compared with the way they were prepared for this study.

Mech (1990) prepared three types of slides (A, B and C).

- Slide A with an unringed specimen
- Slide B with two specimens at different focal depths, both specimens unringed
- Slide C with three specimens at different focal depths, all of them unringed.

In this study two types of slides (A and B) were used.

- Slide A with one ringed specimen
- Slide B with Three ringed specimens at different focal depths

The words were ringed in order to enable the students to locate the area where the words were placed with a naked eye (see Appendix 9 more details). Mech did not ring the specimens because one of the skills she tested was to determine whether the students could locate the specimen on a microscope slide, using a naked eye.

Mech (1990) found that a larger proportion of pupils (69%) were able to identify all 6 specimens in the inquiry group, whereas only 24% of the pupils in the illustrative group found all 6 specimens. In an inquiry group pupils are guided by means of questions and

are required to discover the new information for themselves, while in illustrative group pupils followed the instructions given by the teacher. The results suggested that the methods used to teach the pupils the effective use of the microscope had a greater influence on the pupils' performance.

The results of this study seem better than those from Mech, concerning the effective use of the microscope taking into account that the students were taught more through illustrative methods. More than half of the students (61%) could locate and focus on the specimen representing accurately what the students saw under high power and 71% of the students could locate and focus on the specimens at different focal depths. An explanation for the high performance, is that students may have done well because the slides were ringed indicating the area in which the words were placed. This probably made it easier to locate and focus on the words under the microscope.

2.3 CONCLUSIONS

In conclusion, the written practical test provides answers to three of the research questions.

Most of the students could recognize most of the parts of the microscope. Therefore the answer to the research question 1 was "yes". This was easy for them because before they wrote the written practical test, they were exposed to the microscope several times. In addition, the assistance provided by the lecturer and technician during practicals in handling the microscope helped them to recognize the parts of the light microscope.

Answering the research question 2 was difficult because apparently it had contradictory results. When the students were asked about the *knowledge of how to use the microscope* (eg. Question 2, 4, 5 and 6) most of them performed poorly. Less than 35% of the students passed these questions, indicating that they were unable to use a

microscope correctly and efficiently. However, when they were asked to *perform the physical skills* necessary to use the microscope correctly (eg. Question 7b), a much greater percentage (71%) passed this question.

It is interesting to note that generally students do not have knowledge about the use of the microscope although they can handle the microscope when they are provided with it to solve problems. This is because they have had a chance to practise using the microscope, recalling and repeating the skills several times. The fact that most of the students did not master the knowledge of how to use the microscope, suggests that they do not fully understand how to operate a light microscope correctly and efficiently. Therefore, there is no straightforward "yes" to answer this question.

Regarding research question 3 most students could represent accurately what they saw under the microscope. Therefore the answer to this question was "yes". This was shown by the fact that students could set up the microscope correctly and consequently could locate and focus on the specimen.

3. THE OBSERVATION SCHEDULE

In this section the results of the two checklists are presented and discussed. In each checklist are recorded predetermined categories of skills. The researcher observed and assessed the students during certain practicals.

The checklists provided additional information about whether students could use a microscope correctly and efficiently, and whether they could master the skills involved in preparation of a wet mount slide.

Checklist I addressed the second research question: "Can the students operate a light microscope correctly and efficiently".

Checklist II addressed the fourth research question: "Can the students prepare a wet

mount slide”.

3.1 CHECKLIST I: ASSESSING THE USE OF MICROSCOPE

Checklist I was designed to determine whether the students had mastered the necessary skills needed to use a light microscope correctly and efficiently, to locate and focus on a specimen using low, medium and high power magnification. The students were observed individually during certain practicals.

To determine whether the students could operate a light microscope correctly and efficiently, three important skills under the three categories of magnification, i.e. low, medium and high power were selected. The selected skills were:

- skill 6: focussing with fine focus adjustment knob only under low power magnification;
- skill 10: focussing with fine focus adjustment knob only under medium power magnification;
- skill 13: focussing with fine focus adjustment knob only under high power magnification.

These skills were selected because the students were required to know how to use the fine focus adjustment knob, to get a sharply defined image, and to view the whole specimen. Additionally, if a student can get a well-focussed image, this means that this student could perform the skills which anticipate focussing with fine focus adjustment knob after placing the low, medium and high power in position, respectively.

To ensure that the students were accurately observing the specimen mounted on the permanent slide, the researcher checked by looking through the students' microscope while they were focussing with the fine focus adjustment knob under low, medium and high power magnification. The researcher did not take into account the grade of focus, since this could be different from the students' eye to the researchers' eye. Thus, the researcher was interested to see whether the students were observing the appropriate

specimen. The checklist used for assessing the individual skills assessed are presented in a table in Appendix 2. Table 3 shows the percentages of the students carrying out certain microscope skills.

Table 3: Percentages of the students carrying out certain microscope skills.

Skill number	Percentage (%) of the observed students (n=20)
1: placing the low power objective lens in position to start with	100
2: placing the microscope slide on the stage so that the specimen is centered over the hole	90
3: clipping the microscope slide in position on the microscope stage	95
4: centring the specimen in the field of vision	70
5: focussing on the specimen with the coarse focus adjustment knobs	85
6: refocussing on the specimen with the fine focus adjustment knobs only	55
7: adjusting the light using diaphragm/condenser/transformer	25
8: changing to a medium power magnification	100
9: focussing on the specimen with coarse focus adjustment knobs	70
10: refocussing on the specimen with the fine focus adjustment knobs only	55
11: re- centering the specimen in the field of vision	45
12: changing to high power magnification	100
13: refocussing on the specimen with fine focus adjustment knobs only	70
14: removing the preparation from the microscope stage only after the low power objective lens is put in position	50

Table 3 shows that a larger proportion of the students could perform the skills needed to operate a light microscope correctly and efficiently. However, a certain percentage of students could not use the diaphragm to adjust the light, re-centre the specimen in the field of vision and remove the preparation from the microscope stage only after the low power objective lens was put in position.

The possible explanations, as to why the students did not use the diaphragm were:

- most of the students did not understand the importance of adjusting the light.
- some students knew that they had to adjust the light but forgot the part of the microscope for that purpose.
- for some students, adjusting the light was not necessary since they were doing microscope observations prior to the researcher having administered her checklist.

It was not a serious problem, since it seems that it had not affected the students' performance in carrying out the skills to effectively use the microscope.

Students who did not re-centre the specimen in the field of vision, probably did so because they did not know that before changing to high power magnification it was important that the specimen be well focussed and centred. Consequently, some students experienced difficulties focussing the specimen after changing to high power. Figure 2 shows the percentages of the students performing three most important skills.

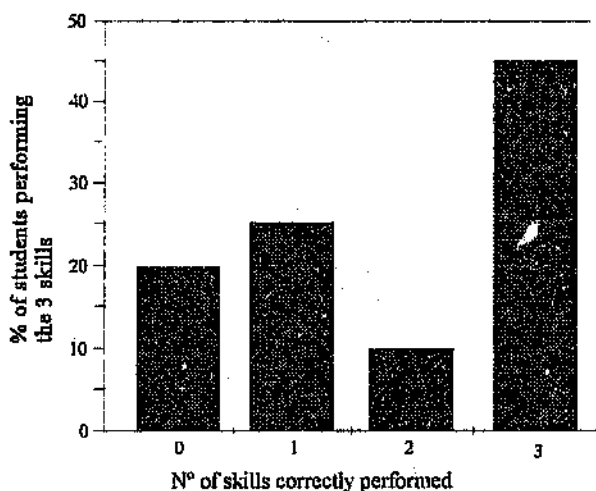


Figure 2: Percentages of the students performing the 3 most important skills.

Figure 2 shows that 45% of the students performed all the 3 skills considered most

important under the 3 categories of magnification. However, some of these students could not perform certain skills listed under the 3 categories of magnification. For example,

- Six students could not use the diaphragm to adjust the light;
- One student could not place the microscope slide on the stage so that the specimen was centred over the hole;
- One student could not focus with the fine focus adjustment knob after changing to medium power;
- One student could not re-centre the specimen before changing to high power;
- Two students did not remove the preparation from the microscope stage only after the low power objective lens was put in position.

These problems may be due to a lack of understanding of the logical sequence of operating the light microscope correctly, or a lack of association with the parts of the microscope with their functions. An approach cited by Barker (1981) is that to understand the use of the microscope knowing the steps involved, seems not sufficient, but practising the steps physically is more important. This means that it is important to link the theoretical component with the practical component in teaching biology because only in that way the practical work can contribute for promoting a meaningful learning of the use of the microscope.

Meanwhile, in assessing the microscope skills, the researcher has noticed that some students who could not perform skill 6 or 10, could perform skill 13. This is an unexpected and illogical result, since in order to focus under high power students needed to focus first under low and medium power. Some probable explanations of the case are presented below.

Twenty five percent of the students performed only skill 13 about focussing with fine focus adjustment knobs after placing the high power objective lens. They may have manipulated the fine focus adjustment knobs in the wrong way since this requires fine movements to get a sharp picture of a specimen under low and medium power

magnification. Another possible explanation is that by changing to high power, these students did not see any clear image. Therefore, they might have decided to return to medium power in order to focus the specimen and re-centre it before changing to high power.

The students' shortcomings in performing some of the 3 important skills are described below:

- One student could perform skills 6 and 10, focussing with the fine focus adjustment knobs at low and medium power magnifications. The student did not re-centre the specimen before changing to high power or the specimen was not clearly focussed at medium power.
- One student could perform skills 10 and 13, focussing with fine focus adjustment knobs at medium and high power magnifications. The student could not perform skill 6, focussing with fine focus adjustment knobs at low power magnification because the student could not perform some skills, which anticipate skill 6. For example, the specimen was not correctly centred in the field of vision. Another explanation is that the student might have moved the fine focus adjustment knobs incorrectly, since this requires fine movements to get the specimen clearly focussed.
- One student performed only skill 6 focussing with fine focus adjustment knobs at low power. The possible interpretation is that the student did not know all the steps needed to use a microscope.

In general, the results suggest that most of the students had mastered a considerable number of the skills needed to operate a light microscope correctly and efficiently since they could perform all the three skills considered important. However, in practice the students continue to have some problems in performing certain skills. On the other hand, the results suggest that most of the students do not have enough comprehension

of the logical sequence to operate a light microscope correctly and efficiently. Observations made during practicals revealed that students relied on extensive assistance by the lecturer and technician in handling the microscope correctly. As explained by Barker (1981) while students are often able to write down the steps involved in the use of a light microscope, many are unable to implement them physically. Therefore, there is a need to assess the laboratory activities and skills to determine whether the students have in fact mastered these skills.

3.2 CHECKLIST II: ASSESSING THE QUALITY OF A WET MOUNT SLIDE

Checklist II was designed to test whether the students could master the skills needed to prepare a wet mount slide. All seven skills were considered important. This means that to get a well prepared slide in terms of quality, students were required to perform all listed skills. The individual skills assessed are presented in a table in Appendix 3. Table 4 shows the percentages of the students performing certain slide preparation skills.

Table 4: Percentages of the students performing certain slide preparation skills.

Skill number	Percentage (%) of the observed students (n=21)
1: is the tissue clean?	66.6%
2: did the students use a transparent section of tissue?	71.4%
3: is the tissue completely flat (i.e. not folded)?	66.6%
4: is the size of tissue approximately the same size as the box □?	42.8%
5: are the individual cells visible?	76.1%
6: are there any large air bubbles on the slide, (bigger than 1/4 field of vision at high power)?	47.6%
7: did the students draw out the excess of water?	76.1%

Table 4 shows that the majority of the students could perform most of the skills needed to prepare a wet mount slide. However, more than half have difficulties removing the correct amount of tissue. Probably, the students did not understand the technique on how this small section of tissue should be cut and removed from the leaf, since in the biology practical guide the amount of the tissue was specified for being a "small rectangle" and the techniques of cutting and removing the tissue are not clearly explained. Only 47.6% of the students avoided large air bubbles in their preparation. The possible explanation is that students who could not avoid large air bubbles in their preparation, experienced difficulties in putting the cover-slip on the microscope slide in the correct way.

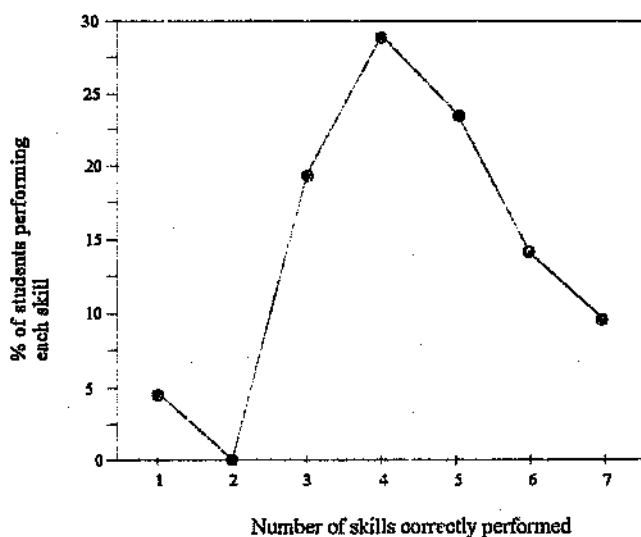


Figure 3: Percentages of the students correctly performing each slide preparation skill.

Figure 3 indicates that the majority of the students (66%) could perform 4 or more skills indicating that they could prepare their wet mount slides. However, a certain percentage of students experienced difficulties in mastering the techniques on how to prepare a wet mount slide. Observations made during practicals, showed that students had difficulties in preparing their wet mounts. They showed difficulties in removing a

correct amount of tissue, using a transparent tissue when it was necessary and avoiding large air bubbles. These failings negatively influenced the quality of the slide made by students. A concrete example was when they were required to observe their wet mounts. They were unable to observe the specimens accurately.

The results of this checklist suggest that most of the students could prepare a wet mount slide. However, the quality of the slides was not excellent. Since students showed difficulties in executing some of the techniques needed to prepare a wet mount slide.

3.3 CONCLUSIONS

In conclusion, the two checklists provided answers to two of the research questions.

Checklist I determined the performance of the physical skills involved in the use of a microscope. The results of this checklist support my findings in the written practical test, that students were able to solve microscope problems when the microscopes were in front of them. As explained in section 2.2 of the written practical test most students can operate a light microscope correctly and efficiently, but they cannot explain the meaning of what they are doing in terms of understanding the concepts.

The results of checklist II indicated that most of the students could master the skills needed to prepare a wet mount slide. Therefore, the answer to the research question 4 was "yes". However, the quality of the slide was not good, since there were some failures in the performance of technical skills.

CHAPTER 5

CONCLUSIONS

1. INTRODUCTION

This study was based on the assumption that an absolute evaluation of a practical component of the cytology section of the BUSCEP biology course would help to determine whether the goals of a major section of the course were being achieved. According to Stake (1967), absolute evaluation means that before making judgement, the evaluator determines whether the intents (stated goals) of the curriculum are consistent with outcomes of the course (students' performance).

In evaluating the practical component of the cytology section, a combination of quantitative and qualitative methods was used. The qualitative data, i.e. field notes were to supplement the obtained quantitative data. In this chapter, some conclusions are drawn and additionally, some limitations and recommendations of the study are discussed.

2. CONCLUSIONS

The results of this study have shown that most of the students lack knowledge and understanding of the use of the microscope and skills required for its effective use. Several other researchers have reported similar problems regarding the effective use of the microscope (Johnstone & Wham, 1982; Beyer & Charlton, 1986; Kapteijn, 1987; Dekker & Fraser 1989; and Mech, 1990). See Chapter 2 for more details. From the results of the written practical test it was possible to state that most of the students could recognize the parts of a light microscope. However, no more than 35%

of students managed to respond correctly in questions relating to the use of the microscope. On the other hand, most of the students did not master the knowledge about focussing length to view the whole specimen. Yet on the contrary, most of them could locate and focus on the specimen representing what they saw under the microscope and could locate and focus on the specimen mounted at different focal depths.

Regarding the checklists most of the students has mastered the skills needed to operate a light microscope correctly and efficiently and, they could master the skills concerning the preparation of wet mount slides. Nevertheless, a certain percentage of the students continue having some shortcomings in the logical sequence of the steps to use the microscope correctly and in the techniques and skills to prepare a wet mount slides.

3. LIMITATIONS OF THE STUDY

Although this study has a great importance in providing insight into the contribution of the science curriculum in assessing laboratory activities and skills, some limitations that may have this study were detected.

1. Translation of English versions of instruments to Portuguese

The language was a major problem that the researcher faced, since she is a Portuguese speaker. Thus, the researcher took most time developing the instruments because they were developed in English and then translated into Portuguese. This was necessary because the main study was conducted at BUSCEP where the students are taught in Portuguese. Even though, the instruments were validated after translation, the onus is on the reader to determine to what extent the content, context and the whole focus of the study are truly reflected in the Portuguese version of the instruments.

2. Sample

The sample choice for this study was for convenience (see section 5.2 of the Chapter 1). Extending the sample would have given more reliable results. Therefore, it was difficult to state to what extent the findings of this study will be applicable. As explained by Guba & Lincoln (1993) the major concern will be on the reader to determine to what extent the research findings are applicable to their particular situation. A further study would be required in this area of research.

3. Period of study

A further limitation may have been the choice of the section to be evaluated. Given the constraints of the cytology section that runs within five weeks planning to evaluate the entire BUSCEP course would have implied to extend the period of this study.

4. RECOMMENDATIONS

To achieve the goals of the practical component of the cytology section of the biology course at BUSCEP, the researcher is recommending the use of the two instruments, namely written practical test and observation schedules as additional assessment procedures to those traditionally used in the biology course (written laboratory report and paper-and pencil-tests).

The written practical test gives the teacher the feedback on the extent to which students have mastered the knowledge of the parts and functions of the microscope and understand how to use the microscope.

The observation schedules provide the feedback whether students understood the logical sequence of the steps needed to operate a light microscope correctly and

efficiently and to prepare a wet mount slide. It is important that teachers give immediate and frequent feedback to the students during practicals. Among other things, these will help the students to understand why performing certain skills are important.

The researcher, is also recommending to future researchers to first study the background of the target group to be involved in the study. This may help to determine whether the students have the same level of prior knowledge which will allow for the generalization of the results. Furthermore, studying the possibility of extending the sample to make the results more reliable is important.

5. CONCLUDING REMARKS

The results of the research have shown that after completion of the practical component of the cytology section of the biology course at BUSCEP, students continue having shortcomings in the knowledge and understanding of the microscope use and skills for its effective use. Thus, the answer for the research question whether the goals of the practical component of the cytology section of the biology course at BUSCEP are being achieved is no. The traditional methods (written laboratory reports and paper-and-pencil tests) used at BUSCEP biology course do not test students' *understanding* of content nor skills of manipulating the microscope and preparing wet mount slides. They test the memorization of the content. Additionally, the dependence on laboratory reports in evaluating laboratory activities and skills can lead students to copy from one another or to invent data (Eglen & Kempa, 1974; and Doran & Dietrich, 1980). The use of the written practical test and observation schedule will contribute to the improvement of the assessment of the laboratory activities during practicals. This will enhance the probability of achieving the goals of the practical component of the cytology section of the biology course at BUSCEP.

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Appendix 1: Written practical test assessing whether students understand how to use the microscope and whether they have knowledge of the parts and functions of the microscope.

Biological Sciences

Laboratory Test

September 1997

Time: 40 minutes

Marks: 40

Examiner: E. Cossa

Special instructions:

1. There are TWO SECTIONS, Section A and Section B.
 2. You have 20 minutes to complete EACH SECTION.
 3. You will be required to CHANGE PLACES to complete each SECTION.
 4. Look on your desk to see which SECTION (A or B) you are seated at. You will start with this section FIRST.
 5. After 20 minutes you will be told to stand up and move to the place ON YOUR RIGHT. If you are sitting at the end of a bench, and there is no place on your right, then you must move to the place BEHIND YOU.
 6. Do not move until you are told to do so.
 7. Write all answers on the question paper.
 8. There are 8 pages to this test paper. Check that you have all pages.
 9. Write your first name AND YOUR SURNAME on your question paper.
-

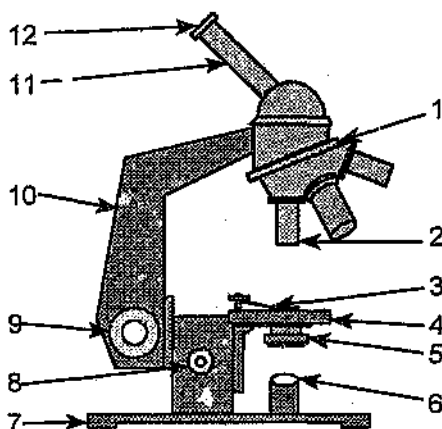
SECTION A

(20 minutes)

30 marks

Question 1

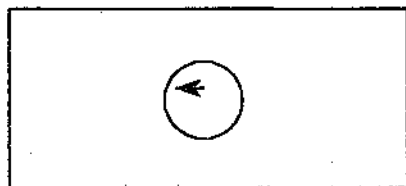
The diagram below shows an optic microscope. Next to each of the numbers 1-12, write down the name of the parts of the microscope. (6 marks)



Question 2

You are observing a microscope slide on which a pond organism has been mounted. While you are looking down through the ocular lens, you notice that the organism is swimming in the direction indicated by the arrow on the diagram below. You also notice that the organism is about to escape from view.

Draw an arrow on the diagram below to indicate the way you would have to move the microscope slide in order to follow the organism. (2 marks)



Question 3

The compound microscope that you have already had the opportunity to use, has three objective lenses. The magnification of the objective lenses is as follows:

- low power : 5X
- medium power : 10X
- high power : 40X

The magnification power of the ocular lens is 10X.

Calculate the magnification of an image seen under medium power. Show your calculation. (2marks)

.....

.....

Question 4

a) You are working in the laboratory with a compound microscope when your friend calls you over and complains that they have lost the specimen. You notice that the high power objective is in position.

In the first column of the table list 3 factors you think could have caused the problems and state the in the second column how you believe they could be resolved. (6marks)

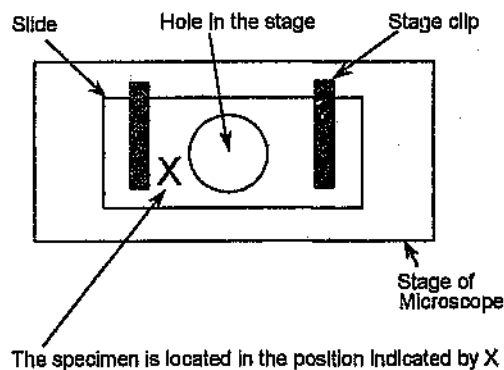
Cause of problem	How to solve problem
1	
2	
3	

b) A second friend calls you over and tells you that they cannot see the specimen clearly. Looking through the ocular lens of the microscope you notice that a clear (well focussed) outline of the specimen can be seen but no internal details are visible.

In the first column list 3 factors you think could have caused the problem and state in the second column how they could be resolved. (6 marks)

Cause of problem	How to solve problem
1	
2	
3	

c) A third friend calls you over and tells you that they are unable to locate the specimen. Your friend has placed the microscope slide on the stage in the following way:



In the first column explain what you would do to help your friend and in the second column explain why this action solves the problem. (2 marks)

How to solve the problem	Why does this solve the problem

Question 5

Below are listed three sets of points, each with two alternatives.

Put a circle around the number of the correct alternative and the explain why the other one is wrong?

- a) i. Only one eye must be kept open when looking through the ocular lens of the microscope.
ii. Both eyes must be kept open when looking through the ocular lens of the microscope.

Why is the one answer wrong?

(2 marks)

.....
.....
.....

- b) i. A microscope slide must be taken off the microscope stage when the low power objective is in position.
ii. A microscope slide must be taken off the microscope stage when the high power objective is in position.

Why is the one answer wrong?

(2 marks)

.....
.....
.....

- c) i. When the high power objective is in position, focussing must be done with the coarse focus adjustment knob.
ii. When the high power objective is in position, focussing must be done with the fine focus adjustment knob.

Why is the one answer wrong?

(2 marks)

.....
.....
.....

SECTION B
(20 MINUTES)
10 MARKS

Question 6

Examine the figure below, (a microscope with slide on the stage). If the focussing length for the objective lens is EXACTLY 10mm, at which level/s (A, B, C) will the specimen be in focus? (2 marks)

Possible answers:

- a) level A and B
- b) level B and C
- c) level A and C
- d) level A, B and C
- e) level A only
- f) level B only
- g) level C only

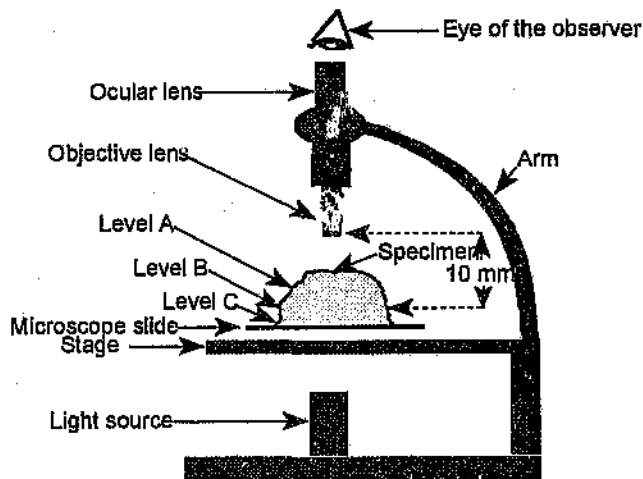
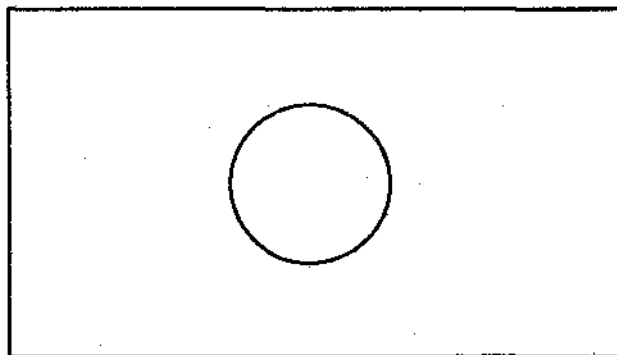


DIAGRAM OF A MICROSCOPE WITH A SLIDE ON THE STAGE
(VIEWED FROM THE SIDE)

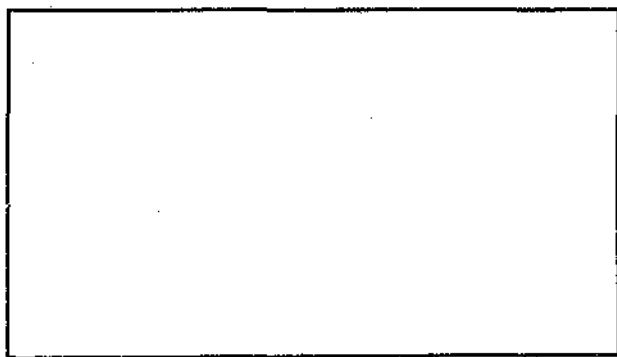
Question 7

You have been provided with TWO microscope slides, SLIDE A and SLIDE B.

- a) Look for the word on the SLIDE A and draw exactly what you can see in the field of vision under the high power objective lens. (2 marks)



- b) On the SLIDE B there is more than one word but they are at different "focal depths". Look for all the words under LOW POWER and write them in the box below. (6 marks)



Appendix 2: Checklist I for assessing use of the microscope

Use the following checklist to test if the students can locate and focus a specimen under low, medium and high power.

Does the student

- 1 ☐ place the low power objective lens in the position to start with?
- 2 ☐ place the microscope slide on the stage so that the specimen is centred over the hole?
- 3 ☐ clip the microscope slide in position on the microscope stage?
- 4 ☐ centre the specimen in the field of vision?
- 5 ☐ focus on the specimen with the coarse focus adjustment knobs?
- 6 ☐ refocus the specimen with the fine focus adjustment knobs only?
- 7 ☐ adjust the light using diaphragm/condenser/transformer?
- 8 ☐ change to a medium power magnification?
- 9 ☐ focus the specimen with the coarse focus adjustment knobs?
- 10 ☐ refocus the specimen with the fine focus adjustment knob only?
- 11 ☐ re-centre the specimen in the field of vision?
- 12 ☐ change to high power magnification?
- 13 ☐ refocus the specimen with fine focus adjustment knob?
- 14 ☐ remove the preparation from the microscope stage only after the low power objective lens is put in position?

Appendix 3: Checklist II for assessing the quality of the microscope slide made by students.

Use the following checklist to test if the students can perform these skills concerning the wet mount slide.

- 1 ☐ Is the slide clean?
- 2 ☐ Did the students use a transparent section of tissue?
- 3 ☐ Is the tissue completely flat (i.e. not folded)?
- 4 ☐ Is the size of the tissue approximately the same size as the box ☐ ?
- 5 ☐ Are the individual cells visible?
- 6 ☐ Are there any large air bubbles on the slide, (bigger than 1/4 field of vision at high power)?
- 7 ☐ Did the students draw out the excess of water?

Appendix 4: Propositional Knowledge and skill Statements representing what is required by first year Biology students completing the practical component of the Cytology section of the BUSCEP Course.

1. Propositional Knowledge Statements

A: About the various parts and functions of the compound light microscope

Students must know that:

a light microscope comprises various parts as follows:

1. the ocular lens magnifies or enlarges the image of the specimen being viewed.
2. the objective lenses magnify the image of the specimen.
3. the optic tube connects the ocular lens and objective lenses.
4. the nose-piece holds the various objective lenses.
5. the stage supports the microscope slide.
6. the mirror/light illuminates the specimen to make it visible.
7. the clamps hold the microscope slide in position.
8. the diaphragm controls the amount of light reaching the specimen.
9. the condenser lens controls the distribution of light in the field of vision of the microscope.
10. the arm connects and supports the parts of the microscope.
11. the base supports the microscope.
12. the coarse focus adjustment knob allows the viewer to get the image more-or less into focus, and to do this easily and rapidly.
13. the fine focus adjustment knob makes very small changes in the distance, so is used for sharp focussing of the image.

B: About the calculation of magnification

Students must know that:

1. magnification is calculated by simply multiplying the magnification of the ocular lens by the magnification of the objective lens in use.

2. a magnification of 400X means that the image being observed is 400X bigger than the object.

C: About the field of vision

Students must know that:

1. the image when viewed under high power magnification shows more details of the specimen than it did under low and medium power.
2. when the specimen is too big it is possible only to see part of it at high power magnification.

D: About the care and storage of a microscope

Students must know that:

1. removal of the microscope from its case is done by using both hands, one supporting the base and other holding the arm of the microscope.
2. by moving the microscope they must set it gently on their desks in the viewing position.
3. by preparing a wet mount slide they must avoid wetting the stage with the mounting medium.
4. the lenses are expensive, therefore students must be careful not to touch/damage them with the fingers or wet them with the mounting medium.
5. the ocular lens, the three objective lenses and the condenser can be cleaned only with appropriate cleaning material. This material is available from laboratory staff.
6. never use the coarse focus knob when the high power lens is in place because it can scratch the slide and damage the lens.
7. the microscope slide must be removed from the stage after use.
8. when they have finished using the microscope, they must:
 - a) rotate the nose-piece to place the low power objective lens in position, before removing the slide. This will prevent the slide and lens scratching each other when the slide is removed.

- b) unplug the microscope and wind the electric cable loosely around the base.
- c) return the microscope to its box, close the box and lock it if this required, and return it to the storage place.

E: About the use of the microscope to locate specimens and focus on them

Students must know that they should:

1. first check the slide with naked eye to know more/less which part of the slide must be in position over the hole on the stage.
2. place the slide on the microscope stage with the specimen in the centre over the hole to ensure that light reaches the specimen.
3. clip the slide into position to prevent that the microscope slide moving out of place.
4. use the diaphragm to get the correct amount of light on the specimen (not too bright or too dim).
5. always use the low power objective lens first, in order to find the specimen.
6. never use the high power lens to locate and focus on a specimen for the first time.
7. to locate and focus on an object under high power one must always focus first with the low and then with the medium power lens before moving to the high power lens
8. the image must always be centred and in perfect focus before moving to a higher power lens.
9. use the coarse focus adjustment knob to get the specimen more or less in focus while looking through the low power objective lens.
10. use the fine focus adjustment knob in order to get a sharp image and to be able to focus the microscope up and down when viewing specimen at different focal depths.
11. use only the fine focus adjustment knob when using the high power objective lens.
12. for more cell detail, a high power lens should be used.

F: About moving the specimen on the microscope

Students must know that:

1. when the specimen on the microscope slide is moved in a particular direction, the image appears to move in the opposite direction.
2. when viewing a live organism which is about to swim out of the field of vision as it is observed under the microscope, they must move the slide in the same direction as the movement of the organism in order to keep it in the field of view.

G: About preparing a temporary wet mount slide

Students must know that in order to prepare temporary wet mounts they must:

1. place a drop of water or mounting medium on the centre of a clean slide with a dropper.
2. use only a small portion of tissue. When it is too big, it will fold and it will not be easy to handle.
3. place the specimen in the drop of water or mounting medium by means of forceps.
4. cover the material with a cover slip.
 - This prevents the mounting medium touching and damaging the objective lens.
 - It stops the material from drying out.
5. use the dissecting needle to lower the cover slip - this prevents the formation of air bubbles.
6. draw the excess of water off the preparation using filter paper.

H: About representing what they see

Students must know that they should:

1. draw the specimen accurately as it is seen under the microscope.
2. place the drawing paper at same side of the microscope as drawing hand, as this makes it easier to draw and look down the ocular lens at the same time.
3. always keep both eyes open: this prevents eye strain and makes it easier to draw.

4. the microscope shows two dimensional images while very often the specimen possesses a third dimension. One should focus on more than one level in order to see the whole specimen.

2. Propositional Skill Statements

A: About the use of the microscope

Students must be able to:

1. click any objective lens in position such that a semicircular black shadow does not appear which can block part of the field of vision, as the light is not reaching the eye.
2. clip the microscope slide in the correct position (over the hole) in the stage.
3. manipulate the diaphragm to get the correct amount of light on the specimen.
4. focus with the coarse focus adjustment knobs and the fine focus adjustment knobs.

B: About preparing a temporary wet mount slide

Students must be able to:

1. place a drop of water or mounting medium in the centre of the slide.
2. remove only a small portion of transparent tissue.
3. use the forceps to place the specimen in the drop of water or mounting medium.
4. take the cover slip with one hand and touch the slide with one edge of this cover slip holding it with an angle of 45 against the slide.
5. use the dissecting needle to lower the cover slip until it touches the drop of water or mounting medium.
6. draw out the excess water.

C: About representing what they see

Students must be able to:

1. draw the specimen so that it matches as closely as possible what is seen under the microscope.
2. distinguish between air bubbles and tissue.

Appendix 5: Translation of the written practical test from English into Portuguese

Ciências Biológicas

Teste Laboratorial

Setembro 1997

Duração: 40 minutos

Pontos: 40

Examinadora: E. Cossa

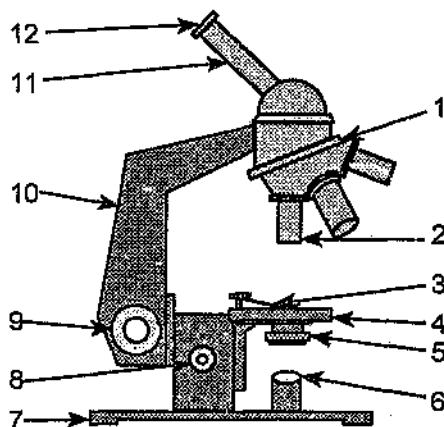
Instruções especiais:

1. O teste contém duas Secções, Secção A e Secção B.
 2. A Secção A é composta por 5 páginas e a Secção B é composta por 2 páginas. Veja se tem todas as páginas.
 3. Precisa de 20 minutos para completar cada Secção.
 4. Depois de completar uma das secções, deverá trocar de lugar afim de completar a outra secção, dirigindo-se para o seu lado direito. Mas, se estiver sentado no fim da fila, e não houver lugar à sua direita, então deve dirigir-se para o lugar atrás de si.
 5. Veja primeiro, qual é a secção colocada no seu lugar. Deve responder primeiro, a essa secção.
 6. Não se levante antes de receber o aviso.
 7. Escreva apenas o seu primeiro nome e o APELIDO na folha de exercício.
 8. Escreva todas as respostas na folha de exercício.
-

SECÇÃO A
(20 minutos)
30 pontos

Pergunta 1

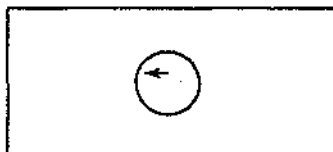
O diagrama em baixo mostra um microscópio óptico composto. Junto a cada um dos números (1 - 12), faça a legenda do microscópio. (6 pontos)



Pergunta 2

Suponha que um estudante esteja observando através da ocular uma preparação na qual se montou um organismo proveniente das águas do lago. Durante a observação, o estudante verificou que o organismo estava nadando na direcção indicada pela seta no diagrama em baixo representado. Ao mesmo tempo, o estudante observou que o organismo estava desaparecendo do campo de visão microscópico.

Desenhe uma seta, no diagrama em baixo, indicando a direcção em que o estudante deveria mover a preparação de modo a seguir o organismo. (2 pontos)



Pergunta 3

O microscópio óptico composto que você já teve a oportunidade de utilizar, tem 3 objectivas. A ampliação das objectivas é a seguinte:

- ampliação menor: 5x
- ampliação média: 10x
- ampliação maior: 40x

A ampliação da ocular é igual a 10x.

Calcule a ampliação de uma imagem vista na ampliação média. Mostre os seus cálculos.
(2 pontos)

.....

.....

Pergunta 4

- a) Um estudante estava trabalhando no laboratório com um microscópio óptico composto quando um dos colegas lhe chamou, e queixou-se em como tinha perdido a imagem. O estudante verificou que a objectiva de maior ampliação estava colocada na posição correcta.

Na primeira coluna da tabela liste 3 factores que pensa que poderão ter causado o problema e na segunda coluna diga como acha que poderá ser resolvido.
(6 pontos)

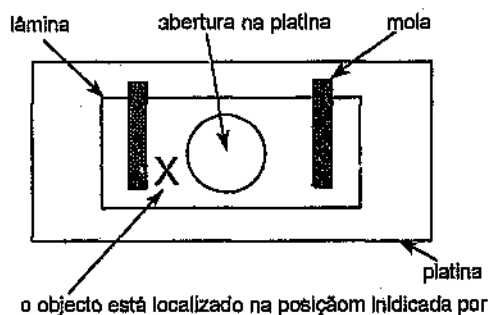
Causa do problema	Como resolver o problema
1.	
2.	
3.	

- b) Um segundo colega, também lhe chamou, dizendo que não conseguia ver a imagem claramente. Olhando através da ocular, o estudante verificou que era possível ver-se um perfil nítido da imagem mas não era possível observar os detalhes internos.

Na primeira coluna da tabela liste 3 factores que pensa que poderão ter causado o problema e na segunda coluna diga como acha que poderá ser resolvido. (6 pontos)

Causa do problema	Como resolver o problema
1.	
2.	
3.	

- c) Um terceiro colega também lhe chamou afirmando que não conseguia localizar a imagem. O seu colega colocou a preparação tal como mostra a figura abaixo.



Na primeira coluna da tabela diga o que o estudante deve fazer para ajudar o seu colega e na segunda coluna explique porque é que esta acção resolve o problema. (2 pontos)

Como resolver o problema	Porque é que a acção resolve o problema

Pergunta 5

Em baixo estão três questões, cada uma com duas alternativas.
Indique por meio de um círculo a alternativa correcta.

- a) i. Somente um olho deve-se manter aberto ao olhar pela ocular.
ii. Ambos os olhos devem-se manter abertos ao olhar pela ocular.

Porque é que a outra resposta está errada?

(2 pontos)

.....

.....

.....

- b) i. A preparação microscópica deve ser retirada da platina quando a objectiva de menor ampliação estiver na posição correcta.
ii. A preparação microscópica deve ser retirada da platina quando a objectiva de maior ampliação estiver na posição correcta.

Porque é que a outra resposta está errada?

(2 pontos)

.....

.....

.....

- c) i. Quando a objectiva de maior ampliação estiver na posição correcta, deve-se focar a preparação com o parafuso macrométrico.
ii. Quando a objectiva de maior ampliação estiver na posição correcta, deve-se focar a preparação com parafuso micrométrico.

Porque é que a outra resposta está errada?

(2 pontos)

.....

.....

.....

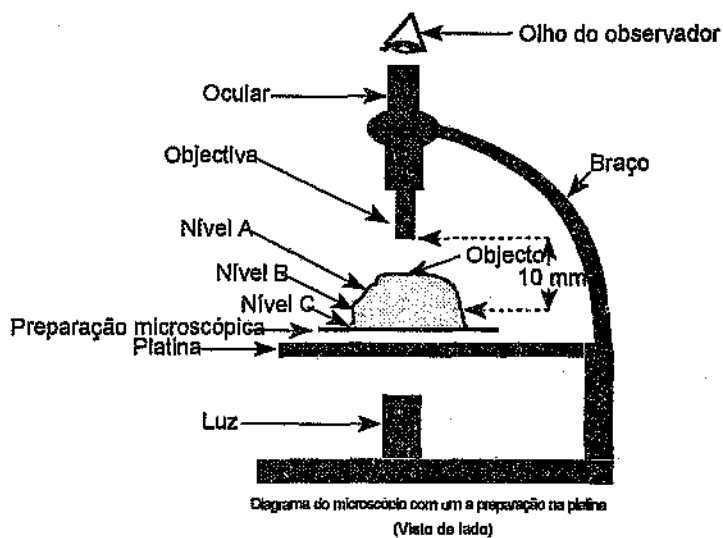
Secção B
(20 minutos)
10 pontos

Pergunta 6

Examine a figura em baixo (um microscópio com uma preparação na platina). Se a distância focal da objectiva, for exactamente de 10 mm, a que nível/níveis (A, B, C) estará o objecto em foco? (2 pontos)

Respostas possíveis:

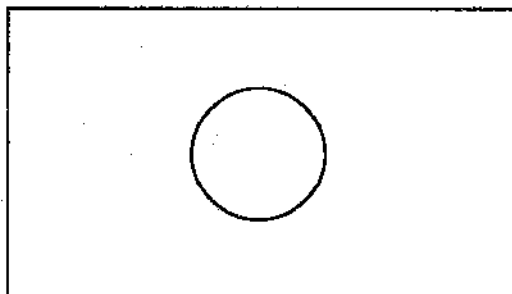
- a) Nível A e B.
- b) Nível B e C.
- c) Nível A e C.
- d) Nível B e C.
- e) Só no nível A.
- f) Só no nível B.
- g) Só no nível C.



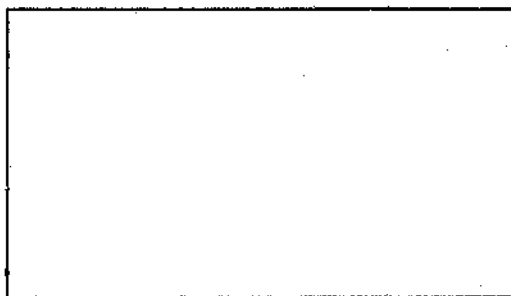
Pergunta 7

Na sua mesa de trabalho estão colocadas duas preparações microscópicas, preparação A e preparação B

- a) Procure a palavra que está na preparação A e desenhe precisamente o que pode ver no campo microscópico utilizando a objectiva de maior ampliação. (2 pontos)



- b) Na preparação B estão mais do que uma palavra colocadas a "níveis diferentes". Procure todas as palavras utilizando só a objectiva de menor ampliação. Escreva todas as palavras que encontrou dentro do rectângulo abaixo. (2 pontos)



Appendix 6: Translation of the checklist I from English Portuguese

Lista de observação para avaliar o uso do microscópio óptico

Utilize a seguinte lista de observação para testar se os estudantes são capazes de localizar e focar a imagem utilizando a objectiva de menor, média e maior ampliação.

Observe se o estudante:

- 1 ☐ Começa com a objectiva de menor ampliação na posição correcta.
- 2 ☐ Coloca a preparação no centro da abertura da platina.
- 3 ☐ Prende a preparação com as molas na posição correcta na platina.
- 4 ☐ Centra a preparação no campo microscópico.
- 5 ☐ Foca a preparação com o parafuso macrométrico.
- 6 ☐ Refoca a preparação só com o parafuso micrométrico.
- 7 ☐ Ajusta a luz usando o diafragma/condensador/transformador.
- 8 ☐ Muda para a ampliação média.
- 9 ☐ Foca a preparação com o parafuso macrométrico.
- 10 ☐ Refoca a preparação só com o parafuso micrométrico.
- 11 ☐ Re-centra a preparação no campo microscópico.
- 12 ☐ Muda para a ampliação maior.
- 13 ☐ Refoca a preparação só com o parafuso micrométrico.
- 14 ☐ Retira a preparação da platina só quando a objectiva de menor ampliação estiver colocada na posição correcta.

Appendix 7: Translation of the checklist II from English into Portuguese

Lista de observação para avaliar a qualidade da preparação microscópica feita pelos estudantes

Utilize a seguinte lista de observação para testar se os estudantes são capazes de realizar estas habilidades relacionadas com a montagem de uma preparação temporária.

- 1 ☐ A lamina esta limpa?
- 2 ☐ O estudante utilizou uma seccao transparent do tecido?
- 3 ☐ O tecido esta completamente liso (nao dobrado)?
- 4 ☐ O tamanho do tecido e aproximadamente o tamanho deste quadrado ☐?
- 5 ☐ E possivel ver celulas individuais?
- 6 ☐ As bolhas de ar na preparacao se existem sao maiores do que 1/4 do campo microscopico observadas a maior ampliacao?
- 7 ☐ O estudante aspirou o excesso de agua na preparacao?

Appendix 8. First version of the instructions for slide preparation (Pilot test)

1. a) Three symbols (\$, + and &), font size 4, were typed in sets of four on A4 paper (eg: \$\$\$\$) and
b) two words (electronic and dog), font size four, were typed on A4 paper in the format described below.
2. The symbols and words were spaced at distance of 4cm apart in three columns. For each row and column the symbols and words were spaced at a distance of 4cm away from each other. The columns were 4cm away from each other in order to spread them across the A4 paper. When the symbols and words were photographed they would be far enough apart that only one set of symbols and one word would be in the field of view.
3. The A4 paper containing the symbols and words was reduced by means of photography to the extent that when the symbols and word were mounted on to microscope slides they could no longer be viewed with the naked eye.
4. The A4 sheets containing the symbols and words were then photographed and printed out on 35mm negatives.
5. Each of set symbol and words on the negatives were cut out and four microscope slides were mounted as indicated below.
 - a) Three different slides A, B and C were mounted at one focal depth.
 - Slide A with long word (electronic) photographed and printed on white background.
 - Slide B with long word (electronic) photographed and printed on blue background.
 - Slide C with short word (dog) photographed and printed on white background.

b) On the Slide D, three different sets of symbols (\$\$\$\$,++++ and &&&&) were mounted between eighteen cover slips so that the symbols were at different focal depths.

- The first set of symbols (\$\$\$\$) was placed on a microscope slide then covered with six cover slips
- The second set of symbols (++++) was put on the top most cover slips and covered with six cover slips.
- The third set of symbols (&&&&) was also put on the top most cover slips of the second set of symbols and then covered with six cover slips.

Appendix 9: Final version of the instructions for slide preparation (Main study)

1. Four words (electronic, field, dog and cat), font size 4, were typed on A4 paper in the format described below.
2. The words were spaced at distance of 4cm apart in three columns. For each row and column, the words were spaced at a distance of 4cm away from each other, i.e. the rows and the columns were 4cm away from each other in order to spread them evenly on the A4 paper. When the words were photographed on the transparency they would be far enough apart that only one word would be visible in the field of view.
3. The A4 paper containing the words was reduced by means of photographed to the extent that when the words were mounted on microscope slides they could no longer be viewed with the naked eye.
4. The A4 sheets containing the words were then photographed and printed out on 35mm negatives.
5. Each word on the negatives was cut out and two types of microscope slides were mounted as indicated below.
 - a) On the slide A, one word (electronic) was mounted at one focal depth.
 - b) On the slide B, three different words (field, dog and cat) were mounted between eighteen cover slips so that the words were at different focal depths.
 - The first word (field) was placed on a microscope slide then covered with six cover slip;
 - The second word (dog) was put on the top most cover slips and covered with six cover slip;
 - The third word (cat) was also put on the top most cover slips of the second word and then covered with six cover slips.

6. A permanent pen was used to circle the words in order to enable the students to locate the area which the words were placed with the naked eye.

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Name of thesis: Evaluation of a practical component of the biology course of the Sasic University Science Course Experimental Project at Universidade Eduardo Mondlane in Maputo.

PUBLISHER:

University of the Witwatersrand, Johannesburg

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